
Environmental Impacts of Options for Disposal of Depleted Uranium Tetrafluoride (UF₄)

**Environmental Assessment Division
Argonne National Laboratory**

Operated by The University of Chicago,
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Director, Environmental Assessment Division
Argonne National Laboratory
Argonne, Illinois 60439-4832
Telephone (630) 252-3107

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ANL/EAD/TM-104

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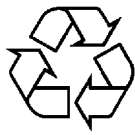
by F.A. Monette, T. Allison,* H.I. Avci, B.M. Biber, J.P. Butler, Y.-S. Chang, J.-J. Cheng, S.M. Folga,* H.M. Hartmann, M.A. Lazaro, D.J. LePoire, D.A. Tomasko, R.A. Van Lonkhuyzen, and B.D. Wilkins

Environmental Assessment Division
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

June 2001

Work sponsored by U.S. Department of Energy, Office of Environmental Management,
and Office of Site Closure—Oak Ridge Office

* Allison and Folga are affiliated with Argonne's Decision and Information Sciences Division.



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NOTATION

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

ACRONYMS AND ABBREVIATIONS

General

BEMR	<i>The 1996 Baseline Environmental Management Report</i>
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
LCF	latent cancer fatality
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level (radioactive) waste
MC&A	materials control and accountability
MCL	maximum contaminant level
MEI	maximally exposed individual
MMES	Martin Marietta Energy Systems
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
PEIS	programmatic environmental impact statement
PM ₁₀	particulate matter with a mean diameter of 10 : m or less
USEC	United States Enrichment Corporation
WM PEIS	<i>Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste</i>

Chemicals

CO	carbon monoxide	UF ₄	uranium tetrafluoride
HC	hydrocarbons	UF ₆	uranium hexafluoride
HF	hydrogen fluoride	UO ₂	uranium dioxide
NO _x	nitrogen oxides	UO ₃ ·H ₂ O	schoepite (hydrous uranium oxide)
SO _x	sulfur oxides	U ₃ O ₈	triuranium octaoxide

UNITS OF MEASURE

cm	centimeter(s)	: m	micrometer(s)
cm ³	cubic centimeter(s)	m	meter(s)
d	day(s)	m ³	cubic meter(s)
ft	foot (feet)	mg	milligram(s)
g	gram(s)	mi ²	square mile(s)
gal	gallon(s)	min	minute(s)
gpm	gallon(s) per minute	mrem	millirem(s)
GWh	gigawatt-hour(s)	MWh	megawatt-hour(s)
ha	hectare(s)	pCi	picocurie(s)
in.	inch(es)	ppm	part(s) per million
km	kilometer(s)	rad	radiation absorbed dose(s)
km ²	square kilometer(s)	rem	roentgen equivalent man
L	liter(s)	te	metric ton(s)
lb	pound(s)	yr	year(s)
: g	microgram(s)		

ENVIRONMENTAL IMPACTS OF OPTIONS FOR DISPOSAL OF DEPLETED URANIUM TETRAFLUORIDE (UF₄)

F.A. Monette, T. Allison, H.I. Avci, B.M. Biwer, J.P. Butler, Y.-S. Chang, J.-J. Cheng,
S.M. Folga, H.M. Hartmann, M.A. Lazaro, D.J. LePoire, D.A. Tomasko,
R.A. Van Lonkhuyzen, and B.D. Wilkins

ABSTRACT

The U.S. Department of Energy (DOE) evaluated options for managing its depleted uranium hexafluoride (UF₆) inventory in the *Programmatic Environmental Impact Statement for the Long-Term Management and Use of Depleted Uranium Hexafluoride* (PEIS) of April 1999. Along with the impacts from other management options, the PEIS discussed the environmental impacts from the disposal of depleted uranium oxide, which could result from the chemical conversion of depleted UF₆. It has been suggested that the depleted UF₆ could also be converted to uranium tetrafluoride (UF₄) and disposed of. This report considers the potential environmental impacts from the disposal of DOE's depleted UF₆ inventory after its conversion to UF₄. The impacts were evaluated for the same three disposal facility options that were considered in the PEIS for uranium oxide: shallow earthen structures, belowground vaults, and mines. They were evaluated for a dry environmental setting representative of the western United States. To facilitate comparisons and future decision making, the depleted UF₄ disposal analyses performed and the results presented in this report are at the same level of detail as that in the PEIS.

1 INTRODUCTION

1.1 BACKGROUND

The U.S. Department of Energy (DOE) evaluated options for managing its depleted uranium hexafluoride (UF₆) inventory in the *Programmatic Environmental Impact Statement for the Long-Term Management and Use of Depleted Uranium Hexafluoride* (depleted UF₆ PEIS) published in April 1999 (DOE 1999). The PEIS discussed the environmental impacts associated with the disposal of two forms of depleted uranium oxide that would result from the chemical conversion of DOE's depleted UF₆ inventory: triuranium octaoxide (U₃O₈) and uranium dioxide (UO₂). Since the publication of the PEIS, it has been suggested that the depleted UF₆ could also be converted to UF₄

and then disposed of. Because of differences in the chemical properties of uranium oxide and UF_4 , it was unclear if the impacts from the disposal of uranium oxide estimated in the PEIS would be representative of the impacts from the disposal of depleted UF_4 . Therefore, the potential impacts from UF_4 disposal were estimated and are discussed in this report.

To facilitate comparisons and future decision making, the level of detail at which the depleted UF_4 disposal analyses were performed and the level at which the results are presented in this report are the same levels as those used in the PEIS for disposal as an oxide. For the same reasons, the assumptions made and the methodologies used to evaluate environmental impacts were similar to those used in the PEIS.

1.2 SCOPE

This report considers the potential environmental impacts associated with the disposal of DOE's depleted UF_6 inventory after its chemical conversion to UF_4 at a conversion facility. The environmental impacts associated with the conversion itself are not included. The scope of this assessment is summarized in Table 1.1 and discussed below.

This report evaluates the disposal of two UF_6 inventories: (1) 560,000 metric tons of depleted UF_6 (contained in about 46,400 cylinders), corresponding to the DOE inventory prior to privatization of the United States Enrichment Corporation (USEC) in 1993, and (2) 705,000 metric tons of UF_6 (contained in about 57,600 cylinders), which is the total inventory for which DOE has been responsible after signing two memoranda of agreement with USEC in 1998. Both inventories were considered to facilitate comparisons with the PEIS. Following conversion, the two UF_6 inventories correspond to 500,000 and 630,000 metric tons of UF_4 , respectively. For each inventory, impacts were evaluated for disposal in both 30-gal (110-L) and 55-gal (208-L) drums. A parametric analysis was also performed, similar to what was done for disposal as an oxide in the PEIS, to evaluate the disposal of 50% and 25% of the original DOE inventory.

The potential environmental impacts from disposal of UF_4 were evaluated for the same three disposal facility options that were considered in the PEIS for uranium oxide: shallow earthen structures, belowground vaults, and mines. Although the PEIS evaluated two physical forms for disposal, grouted and ungrouted oxide, only ungrouted UF_4 is evaluated in this report. Grouted UF_4 was considered but is not analyzed in detail because UF_4 forms the corrosive product hydrogen fluoride (HF) in the presence of water and is thus considered not suitable for grouting (Folga and Kier 2001).

The environmental impacts from disposal of UF_4 were evaluated for a representative dry environmental setting, typical of the western United States. In the PEIS, the disposal analyses were conducted for both a representative dry setting and a representative wet setting (typical of the eastern

TABLE 1.1 Scope of the Depleted UF₄ Disposal Analysis

Parameter	Assumption
General approach	Same assumptions and methodologies as those used for the disposal of depleted uranium oxide in the depleted UF ₆ PEIS (as appropriate)
Disposal form	Bulk (ungrouned) uranium tetrafluoride (UF ₄)
Disposal options	Shallow earthen structures Vaults Mine
Source of engineering data	Folga and Kier (2001)
UF ₆ inventory considered	Two inventories: (1) 560,000 metric tons (pre-1993 DOE inventory) (2) 705,000 metric tons (above plus inventory either transferred or to be transferred from USEC)
Equivalent UF ₄ inventory	(1) 500,000 metric tons (2) 630,000 metric tons
Packaging options	Two options for each inventory: (1) 30-gal drums (2) 55-gal drums
Environmental setting	Representative “dry” setting, as defined and evaluated in the PEIS
Emplacement period	(1) 20 years for 560,000 metric tons of depleted UF ₆ (2) 25 years for 705,000 metric tons of depleted UF ₆
Parametric analysis	Disposal of 25% and 50% of 560,000 metric tons of depleted UF ₆

United States). The PEIS showed that disposal as an oxide in a wet environment would probably not meet the current regulatory requirements for disposal of radioactive material, a finding consistent with previous analyses by the U.S. Nuclear Regulatory Commission (NRC 1994a). In addition, an arid climate provides the most favorable disposal conditions and is consistent with current disposal practices. Consequently, disposal of UF_4 in a wet environmental setting was not analyzed in this report. A specific arid location for the disposal facility, which could be a DOE facility or a commercial facility operating under a radioactive materials license issued by the NRC or an Agreement State, will be determined at a later date.

The technical basis for this analysis was the report *Engineering Analysis for Disposal of Depleted Uranium Tetrafluoride (UF_4)* (Folga and Kier 2001). This UF_4 engineering report was prepared specifically to support the UF_4 disposal analysis. To facilitate comparisons with the PEIS, the UF_4 engineering report used the same methods and assumptions, to the extent practicable, as those used in the *Depleted Uranium Management Program; the Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride* (Lawrence Livermore National Laboratory [LLNL] 1997), which was prepared to support the PEIS. For each disposal option, the UF_4 engineering report provides preconceptual UF_4 disposal facility design data, including descriptions of facility layouts and resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios. In addition, the report provides a brief discussion of historical UF_4 disposal experience that supports future consideration of UF_4 as a suitable disposal form.

As in the PEIS, the environmental impacts from the disposal of UF_4 were estimated for two phases: (1) the operational phase, which includes construction of the facility and the period in which waste would be actively placed into disposal units, and (2) the post-closure phase, which considers hundreds of years in the future, beyond the time that any engineered disposal facilities would be expected to function as designed. All disposal facilities were assumed to fail, or release waste to the environment, at the end of an institutional control period. (Failure was assumed to occur around the year 2140, 100 years after site closure.)

The potential environmental impacts from disposal of UF_4 were estimated for an operational period of 40 years. It was assumed that waste emplacement would occur over 20 years for the 560,000 metric ton UF_6 inventory and over 25 years for the 705,000 metric ton inventory. In addition, long-term impacts from potential groundwater contamination were estimated for a period of 1,000 years following the failure of the disposal facility. Consequences were evaluated in the areas of human health and safety (impacts from both normal operations and accidents), air quality, water and soil, socioeconomics, ecology, waste management, resource requirements, land use, cultural resources, and environmental justice. The assessment considered impacts to workers and the public that could result from construction of a disposal facility, normal operation of the facility, accidents, and transportation of UF_4 to the disposal facility.

2 SUMMARY OF UF₄ DISPOSAL IMPACTS

This section provides a summary of the potential environmental impacts associated with the disposal of depleted UF₄. The summary is based on the information provided in the remainder of this report. As described above, potential environmental impacts were evaluated for shallow earthen structures, vaults, and a mine during two phases: the operational phase and post-closure phase. The estimated environmental impacts during the operational phase are summarized in Table 2.1; post-closure impacts are summarized in Table 2.2. Results are presented in the same format as that used in the PEIS to facilitate comparisons.

Analysis of the operational phase covered facility construction and the time during which waste would be actively placed in disposal units. Analysis of the post-closure phase considered potential impacts 1,000 years after the disposal units were assumed to fail (i.e., release uranium material beyond the boundaries of the disposal unit).

The following is a general summary of potential environmental impacts during the operational phase taken from information provided in this report in Table 2.1, Section 6 (operational impacts), and Section 8 (transportation impacts):

- C ***Potential Adverse Impacts.*** Potential adverse impacts during the operational phase would be small and generally similar for all three disposal facility options and both packaging options. Minor to moderate impacts, such as particulate air emissions (i.e., dust), could occur during construction activities, although these impacts would be temporary and easily mitigated by common engineering and construction practices. Potential health impacts during waste emplacement activities would likely be small and limited to involved and noninvolved workers. (Involved workers are defined as those workers directly involved with the handling and disposal of the depleted UF₄; noninvolved workers are those on-site workers who are not directly involved with disposal activities.) Involved workers would be exposed to low levels of external radiation and subject to some risk of injury or fatality from occupational accidents. Low-probability facility accidents that could release UF₄ to the environment could occur during interim storage and handling; however, the maximum consequences of such accidents were estimated to be well below levels expected to cause an appreciable health risk to noninvolved workers or the public.

TABLE 2.1 Impacts from UF₄ Disposal Options during the Operational Phase^a

Disposal in Shallow Earthen Structures	Disposal in Vaults	Disposal in a Mine
<i>Human Health – Normal Operations: Radiological^b</i>		
Involved Workers: Total collective dose: 280 – 320 person-rem (350 – 400 person-rem) Total number of LCFs: 0.1 LCF (0.1 – 0.2 LCF) Noninvolved Workers: No impacts General Public: No impacts	Involved Workers: Total collective dose: 280 – 320 person-rem (350 – 400 person-rem) Total number of LCFs: 0.1 LCF (0.1 – 0.2 LCF) Noninvolved Workers: No impacts General Public: No impacts	Involved Workers: Total collective dose: 360 – 400 person-rem (450 – 500 person-rem) Total number of LCFs: 0.1 – 0.2 LCF (0.1 – 0.2 LCF) Noninvolved Workers: No impacts General Public: No impacts
<i>Human Health – Normal Operations: Chemical</i>		
Noninvolved Workers: No impacts General Public: No impacts	Noninvolved Workers: No impacts General Public: No impacts	Noninvolved Workers: No impacts General Public: No impacts
<i>Human Health – Accidents: Radiological</i>		
Bounding accident: Earthquake damage to product receiving building Bounding accident frequency: 1 in 100 years to 1 in 10,000 years Release: 275 lb UF ₄ Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 5 rem Risk of LCF to MEI: 0.002 Collective dose: 0.22 person-rem Number of LCFs: 0.00009 General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.039 rem Risk of LCF to MEI: 2×10^{-5} Collective dose to population within 50 miles: 0.05 person-rem Number of LCFs in population within 50 miles: 3×10^{-5} LCF	Bounding accident: Earthquake damage to product receiving building Bounding accident frequency: 1 in 100 years to 1 in 10,000 years Release: 275 lb UF ₄ Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 5 rem Risk of LCF to MEI: 0.002 Collective dose: 0.22 person-rem Number of LCFs: 0.00009 General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.039 rem Risk of LCF to MEI: 2×10^{-5} Collective dose to population within 50 miles: 0.05 person-rem Number of LCFs in population within 50 miles: 3×10^{-5} LCF	Bounding accident: Earthquake damage to product receiving building Bounding accident frequency: 1 in 100 years to 1 in 10,000 years Release: 275 lb UF ₄ Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 5 rem Risk of LCF to MEI: 0.002 Collective dose: 0.22 person-rem Number of LCFs: 0.00009 General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.039 rem Risk of LCF to MEI: 2×10^{-5} Collective dose to population within 50 miles: 0.05 person-rem Number of LCFs in population within 50 miles: 3×10^{-5} LCF

TABLE 2.1 (Cont.)

Disposal in Shallow Earthen Structures	Disposal in Vaults	Disposal in a Mine
Human Health – Accidents: Chemical		
<p>Bounding accident: Earthquake damage to product receiving building</p> <p>Bounding accident frequency: 1 in 100 years to 1 in 10,000 years</p> <p>Release: 275 lb UF₄</p> <p>Noninvolved Workers: Bounding accident consequences (per occurrence):</p> <p style="padding-left: 40px;">Number of persons with potential for adverse effects: 3.5 persons</p> <p style="padding-left: 40px;">Number of persons with potential for irreversible adverse effects: 2.7 persons</p> <p>General Public: Bounding accident consequences (per occurrence):</p> <p style="padding-left: 40px;">Number of persons with potential for adverse effects: 2.5 persons</p> <p style="padding-left: 40px;">Number of persons with potential for irreversible adverse effects: 0.8 person</p>	<p>Bounding accident: Earthquake damage to product receiving building</p> <p>Bounding accident frequency: 1 in 100 years to 1 in 10,000 years</p> <p>Release: 275 lb UF₄</p> <p>Noninvolved Workers: Bounding accident consequences (per occurrence):</p> <p style="padding-left: 40px;">Number of persons with potential for adverse effects: 3.5 persons</p> <p style="padding-left: 40px;">Number of persons with potential for irreversible adverse effects: 2.7 persons</p> <p>General Public: Bounding accident consequences (per occurrence):</p> <p style="padding-left: 40px;">Number of persons with potential for adverse effects: 2.5 persons</p> <p style="padding-left: 40px;">Number of persons with potential for irreversible adverse effects: 0.8 person</p>	<p>Bounding accident: Earthquake damage to product receiving building</p> <p>Bounding accident frequency: 1 in 100 years to 1 in 10,000 years</p> <p>Release: 275 lb UF₄</p> <p>Noninvolved Workers: Bounding accident consequences (per occurrence):</p> <p style="padding-left: 40px;">Number of persons with potential for adverse effects: 3.5 persons</p> <p style="padding-left: 40px;">Number of persons with potential for irreversible adverse effects: 2.7 persons</p> <p>General Public: Bounding accident consequences (per occurrence):</p> <p style="padding-left: 40px;">Number of persons with potential for adverse effects: 2.5 persons</p> <p style="padding-left: 40px;">Number of persons with potential for irreversible adverse effects: 0.8 person</p>
Human Health — Accidents: Physical Hazards		
<p>Construction and Operations: All Workers: Less than 1 (0.13 – 0.16) fatality, approximately 88 – 105 injuries (Less than 1 (0.15 – 0.17) fatality, approximately 103 – 123 injuries)</p>	<p>Construction and Operations: All Workers: Less than 1 (0.23 – 0.25) fatality, approximately 138 – 158 injuries (Less than 1 (0.28) fatality, approximately 166 – 187 injuries)</p>	<p>Construction and Operations: All Workers: Less than 1 (0.59 – 0.66) fatality, approximately 262 – 300 injuries (Less than 1 (0.66 – 0.76) fatality, approximately 296 – 347 injuries)</p>
Air Quality		
<p>Construction: 24-hour PM₁₀ concentration potentially as large as 27% of standard; other criteria pollutant concentrations less than 13% of respective standards</p> <p>Operations: Annual NO_x concentration potentially as large as 15% of standard; other criteria pollutant concentrations less than 15% of respective standards</p>	<p>Construction: 24-hour PM₁₀ concentration potentially as large as 27% of standard; other criteria pollutant concentrations less than 13% of respective standards</p> <p>Operations: Annual NO_x concentration potentially as large as 15% of standard; other criteria pollutant concentrations less than 15% of respective standards</p>	<p>Construction: 24-hour PM₁₀ concentration potentially as large as 27% of standard; other criteria pollutant concentrations less than 13% of respective standards</p> <p>Operations: Annual NO_x concentration potentially as large as 15% of standard; other criteria pollutant concentrations less than 15% of respective standards</p>

TABLE 2.1 (Cont.)

Disposal in Shallow Earthen Structures	Disposal in Vaults	Disposal in a Mine
<i>Water^b</i>		
<p>Construction: Negligible impacts to surface water and groundwater</p> <p>Operations: None to negligible impacts to surface water and groundwater</p>	<p>Construction: Negligible impacts to surface water and groundwater</p> <p>Operations: None to negligible impacts to surface water and groundwater</p>	<p>Construction: Negligible impacts to surface water and groundwater</p> <p>Operations: None to negligible impacts to surface water and groundwater</p>
<i>Soil^b</i>		
<p>Construction: Negligible, but temporary, impacts</p> <p>Operations: No impacts</p>	<p>Construction: Moderate to large, but temporary, impacts</p> <p>Operations: No impacts</p>	<p>Construction: Moderate to large, but temporary, impacts</p> <p>Operations: No impacts</p>
<i>Socioeconomics</i>		
<p>Construction: Potential moderate impacts on employment and income</p> <p>Operations: Potential moderate impacts on employment and income</p>	<p>Construction: Potential moderate impacts on employment and income</p> <p>Operations: Potential moderate impacts on employment and income</p>	<p>Construction: Potential moderate impacts on employment and income</p> <p>Operations: Potential moderate impacts on employment and income</p>
<i>Ecology</i>		
<p>Construction: Potential moderate impacts to vegetation and wildlife</p> <p>Operations: Potential adverse impacts to aquatic biota</p>	<p>Construction: Potential moderate impacts to vegetation and wildlife (Potential moderate to large impacts to vegetation and wildlife)</p> <p>Operations: Potential adverse impacts to aquatic biota</p>	<p>Construction: Potential large impacts to vegetation and wildlife</p> <p>Operations: Potential adverse impacts to aquatic biota</p>
<i>Waste Management</i>		
Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations
<i>Resource Requirements</i>		
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements on the local or national scale are expected; impacts of electrical requirements for mine excavation depend on site location

TABLE 2.1 (Cont.)

Disposal in Shallow Earthen Structures	Disposal in Vaults	Disposal in a Mine
<i>Land Use</i>		
Use of approximately 46 to 55 acres; potential moderate impacts (Use of approximately 57 to 67 acres; potential moderate impacts)	Use of approximately 67 to 82 acres; potential moderate impacts (Use of approximately 82 to 97 acres; potential moderate impacts)	Use of approximately 418 to 587 acres; potential large impacts, including impacts from disposal of excavated material and potential off-site traffic impacts during construction (Use of approximately 547 to 770 acres; potential large impacts, including impacts from disposal of excavated material and potential off-site traffic impacts during construction)

^a Impacts are presented for the operational period for disposal of 560,000 metric tons of UF₆; impacts from the disposal of 705,000 metric tons of UF₆ are shown in parentheses when different. Notation: LCF = latent cancer fatality; MEI = maximally exposed individual.

^b Radiological impacts are presented as ranges resulting from disposal in 30-gal and 55-gal drums.

C *Shallow Earthen Structure, Vault, or Mine.* The potential impacts from disposal in a shallow earthen structure, vault, or mine are similar. However, disposal in a mine could create slightly larger potential impacts if the mine would have to be excavated.

C *Transportation.* Disposal of UF₄ would require the shipment of the depleted UF₄ from a conversion plant to the disposal facility. The UF₄ would be packaged in 30-gal or 55-gal drums and shipped by either truck or train, in accordance with DOE and U.S. Department of Transportation (DOT) regulatory requirements. The greatest risk from UF₄ shipments would be from typical traffic accidents, unrelated to the radiological or chemical nature of the UF₄. Although less than 1 traffic fatality would be expected to result from shipment of the entire inventory, these vehicle-related risks would be about 5 times larger than the radiological and chemical risks combined.

The potential impacts estimated for the post-closure phase are subject to a great deal of uncertainty because of the extremely long time period considered and the dependence of predictions on the behavior of the waste material as it interacts with soil and water in a distant future environment. The post-closure impacts would depend greatly on the specific disposal facility design and site-specific characteristics. Because of these uncertainties, the assessment assumptions were generally selected to produce conservative estimates of impact, that is, they tend to overestimate the expected impact. Changes in key disposal assumptions could yield significantly different results (see Section 7).

TABLE 2.2 Impacts from UF₄ Disposal Options during the Post-Closure Phase^{a,b}

Disposal in Shallow Earthen Structures	Disposal in Vaults	Disposal in a Mine
<i>Human Health: Radiological^c</i>		
General Public: Annual dose to MEI: $< 2 \times 10^{-8}$ mrem/yr $(< 3 \times 10^{-8}$ mrem/yr) Annual cancer risk to MEI: $< 1 \times 10^{-14}$ per year $(< 1 \times 10^{-14}$ per year) Collective dose to population within 50 miles: not determined Number of LCFs in population within 50 miles: not determined	General Public: Annual dose to MEI: $< 3 \times 10^{-8}$ mrem/yr $(< 3 \times 10^{-8}$ mrem/yr) Annual cancer risk to MEI: $< 1 \times 10^{-14}$ per year $(< 2 \times 10^{-14}$ per year) Collective dose to population within 50 miles: not determined Number of LCFs in population within 50 miles: not determined	General Public: Annual dose to MEI: $< 2 \times 10^{-6}$ mrem/yr $(< 3 \times 10^{-6}$ mrem/yr) Annual cancer risk to MEI: $< 1 \times 10^{-12}$ per year $(< 1 \times 10^{-12}$ per year) Collective dose to population within 50 miles: not determined Number of LCFs in population within 50 miles: not determined
<i>Human Health: Chemical</i>		
No impacts to MEI of the general public from groundwater	No impacts to MEI of the general public from groundwater	No impacts to MEI of the general public from groundwater
<i>Water</i>		
Negligible impact to groundwater quality from uranium contamination	Negligible impact to groundwater quality from uranium contamination	Negligible impact to groundwater quality from uranium contamination
<i>Ecology</i>		
Negligible impacts to wetlands and aquatic biota from surface water and groundwater contamination	Negligible impacts to wetlands and aquatic biota from surface water and groundwater contamination	Negligible impacts to wetlands and aquatic biota from surface water and groundwater contamination

^a Impacts for the post-closure phase were calculated for a time 1,000 years after each disposal facility was assumed to fail. Impacts are presented for the disposal of the 560,000 metric tons of UF₆; impacts from the disposal of the 705,000 metric tons of UF₆ are shown in parentheses when different. Notation: LCF = latent cancer fatality; MEI = maximally exposed individual.

^b All disposal facilities would be designed to contain the waste material for at least hundreds of years. Shallow earthen structures would be expected to last several hundred years before failure; vaults and mines would be expected to last several hundreds to thousands of years before failure.

^c Radiological impacts are presented as the maximum values considering disposal in both 30-gal and 55-gal drums.

The following general summary of potential environmental impacts during the post-closure phase is taken from information in Table 2.2 and Section 7 (post-closure impacts):

- C ***Potential Adverse Impacts.*** For all disposal options, essentially no impacts would occur for a disposal facility in a dry environmental setting within 1,000 years after the facility was assumed to fail. Although UF_4 was assumed to be released to the environment, the relatively low solubilities of UF_4 and the uranium compounds formed by reaction of UF_4 with infiltrating water, and the low water infiltration rate typical of dry environmental settings, would result in only a very small amount of uranium reaching the groundwater table within 1,000 years. The maximum dose to an individual assumed to live at the edge of the disposal site and use the contaminated water was estimated to be extremely small, approximately 1×10^{-6} mrem/yr. Possible exposures (on the order of 10 rem/yr) could occur for shallow earthen structures and vaults if the cover material were to erode and expose the uranium material; however, this situation would not occur until several thousand years after emplacement or failure, and the exposure could be eliminated by adding new cover material to the top of the waste area.
- C ***Shallow Earthen Structure, Vault, or Mine.*** Because of the long time periods considered and the fact that the calculations were performed for a time of 1,000 years *after* each facility was assumed to fail, the potential impacts from disposal in a shallow earthen structure, vault, or mine would be very similar. However, shallow earthen structures would be expected to contain the waste material for a period of at least several hundred years before failure, whereas vaults or a mine would be expected to last even longer — from several hundred years to a thousand years or more. Therefore, vault and mine disposal would provide longer protection of waste. In addition, a vault and a mine would be expected to provide additional protection against erosion of the cover material (and possible surface exposure of the waste material) when compared with shallow earthen structures. The exact time that any disposal facility would perform as designed would depend on the specific facility design and site characteristics and is beyond the scope of this assessment.

3 DEPLETED UF₄ BACKGROUND INFORMATION

3.1 PHYSICAL CHARACTERISTICS OF UF₄

Uranium tetrafluoride (UF₄) is often called green-salt because of its characteristic color. Depleted UF₄ is a solid composed of agglomerating particles. Its texture is similar to that of baking soda. It is nonvolatile and nonhygroscopic but only slightly soluble in water: about 40 parts per million (ppm) at room temperature (Katz et al. 1986). It has a particle density of 6.5 g/cm³; however, its bulk density depends on the production process and the properties of the starting uranium compounds, ranging between 2.0 and 4.5 g/cm³. It is generally an intermediate in the conversion of UF₆ to either uranium oxide or uranium metal. The physical properties of depleted UF₄ are summarized in Table 3.1.

After exposure to water, UF₄ slowly dissolves and undergoes hydrolysis, forming several possible uranium compounds and HF. The time for hydrolysis can be significant. Tomasko (2001) presents a discussion of the chemical reactions possible when UF₄ reacts with water in a disposal environment. Possible reaction products include U₃O₈, schoepite (UO₃·2H₂O), and several uranium complexes. The final form of uranium in solution in the groundwater below a disposal facility is a complex function of the reaction time, physical and chemical attributes of the disposal facility, and geochemistry of the receiving water (Tomasko 2001).

3.2 SUITABILITY OF UF₄ FOR DISPOSAL

One potential concern with the disposal of depleted UF₄ has been the fact that it reacts slowly with moisture at ambient temperature and releases HF, which potentially could enhance the corrosion rate of disposal packages or the disposal facility itself. In addition, UF₄ has a higher solubility in water than the uranium oxides U₃O₈ and UO₂. These were two of the reasons that the conversion to UF₄ and disposal of UF₄ were considered in the PEIS but not analyzed in detail. Specifically, the disposal of UF₄ was not considered in detail in the PEIS for the following reasons:

- C A 1994 DOE Request for Recommendations (59 FR 56324) solicited suggestions for potential uses of depleted UF₆ and for any technologies that could facilitate the long-term management of depleted UF₆. No responses suggested conversion to UF₄ or disposal as UF₄.

TABLE 3.1 Physical Properties of UF₄

Melting Point (EC)	Bulk Density (g/cm ³)	Solubility in Water Neutral pH	Inhalation Solubility Class ^a
960±5	2.0–4.5	Very slightly soluble	W

^a D, W, and Y are inhalation solubility classes established by the International Commission on Radiation Protection. Class D material is very soluble; lung retention time is *days*. Class W material is relatively insoluble; lung retention time is *weeks*. Class Y material is relatively insoluble; lung retention time is *years*.

Source: Martin Marietta Energy Systems (MMES 1990).

- C DOE and its contractors felt that there was no particular environmental advantage to UF₄ over oxides. On the contrary, there was some concern that UF₄ may not meet the waste acceptance criteria for low-level waste (LLW) disposal sites because of HF generation when UF₄ reacts with water and because UF₄ has a higher solubility than oxides.
- C For practical reasons, there was a desire to limit the number of options analyzed in detail in the PEIS to a reasonable number.
- C DOE held three scoping meetings in February 1996, soon after the Notice of Intent to prepare the PEIS was issued. There was also a 60-day comment period. Only one individual at one meeting suggested conversion to UF₄ or disposal as UF₄. Similarly, when the draft PEIS was issued, there was a lengthy public review period (120 days). Approximately 600 comments were received; no comments mentioned conversion to UF₄ or disposal as UF₄.

Recent information, summarized below, supports future consideration of UF₄ as a suitable disposal form.

- C *Folga and Kier (2001)*. This engineering analysis report for UF₄ disposal reports that a much smaller amount of UF₄ than was considered here (approximately 1,870 metric tons) was disposed of in a shallow land LLW disposal facility at the Nevada Test Site (NTS) in the past. Disposal was accomplished by using standard disposal boxes, without any additional overpacking or treatment of the bulk depleted UF₄. A review of the properties of depleted UF₄ in bulk form by personnel from NTS and the Fernald Site before its shipment to NTS did not reveal any major issues associated with the reactivity of UF₄.

- C *Croff et al. (2000)*. This study by Oak Ridge National Laboratory evaluated the acceptability of several depleted uranium conversion products at potential LLW disposal sites to provide a basis for DOE decisions on the preferred depleted uranium product form. The study concluded that depleted UF_4 should be acceptable for near-surface disposal at sites such as NTS and Envirocare. Although some characteristics (e.g., very fine particles, sorbed HF) could limit the acceptability of depleted UF_4 for disposal, these characteristics reportedly can be controlled via proper technical specifications imposed on the product forms.
- C *Tomasko (2001)*. This report evaluated potential groundwater concentrations following failure of a UF_4 disposal facility in a representative dry environment for a range of site characteristics. The results of the evaluation, discussed in more detail in Section 7, indicate that uranium groundwater concentrations would remain well below levels of concern for thousands of years, even under conservative site assumptions.

4 ASSESSMENT ASSUMPTIONS AND METHODOLOGY

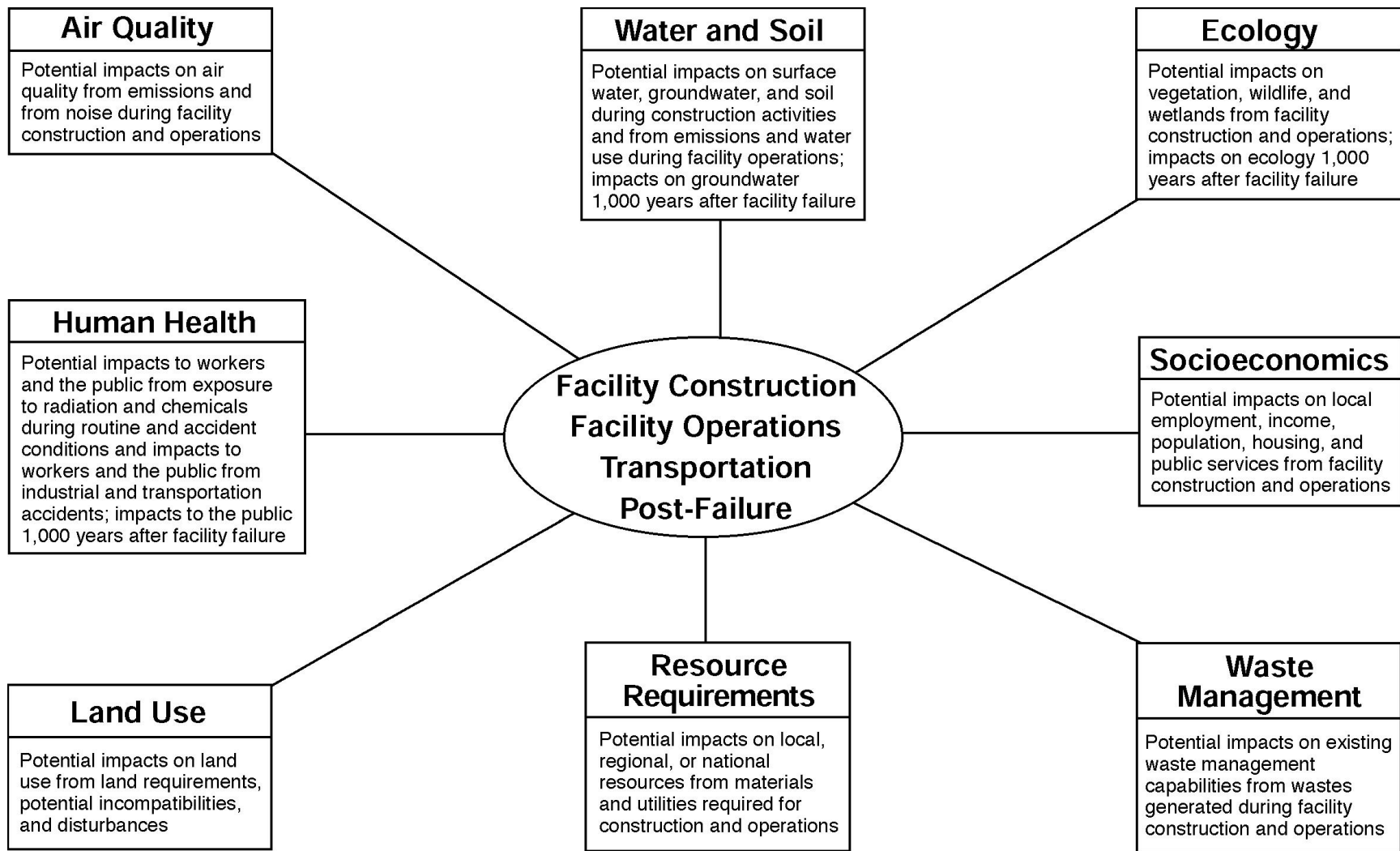
The areas of potential environmental impact discussed in this report are the same as those discussed in the PEIS (Figure 4.1). For each technical area, analytical methods similar or identical to those used for the PEIS were used to estimate the potential impacts from construction, operations, and accidents for each of the UF₄ disposal options. A complete discussion of the methods used for each technical area is provided in Chapter 4 and Appendix C of the PEIS. Changes to methods or assumptions are noted in Chapters 6 and 7, where appropriate.

In general, the assumptions used to analyze UF₄ disposal were the same as those used in the PEIS. A summary of the representative dry environmental setting assumptions is presented in Table 4.1.

The results of the UF₄ disposal analysis are presented in this report in the same manner in which the PEIS results were presented. Potential impacts to human health are summarized quantitatively by presenting the estimated number of health effects among workers and members of the general public from potential exposures to radiation and chemicals over the duration of the disposal activities. Potential impacts to water and air quality are summarized by indicating whether or not the estimated pollutant concentrations would be above or below applicable guidelines or standards. Other areas of impact, primarily those for which guidelines or standards are not specifically defined (such as ecological and waste management impacts), are summarized qualitatively by using the terms negligible to low, moderate, and large. A summary of the criteria used to define impacts is provided in Table 4.2.

TABLE 4.1 Representative Dry Environmental Setting Assumptions as Defined in the PEIS

Parameter	Assumption
Population density	Generic setting with low population density (6 persons/km ²)
Groundwater	Disposal facility located either 500 ft (shallow earthen structure or vault) or 100 ft (mine) above the water table
Precipitation	10 in. per year
Water infiltration	1% of annual precipitation
Meteorological conditions	Five Western locations were used as examples to determine a range of meteorological conditions for air dispersion



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FIGURE 4.1 Areas of Potential Impact Evaluated in the Depleted UF₄ Disposal Analysis

TABLE 4.2 General Criteria Used to Summarize and Describe the Magnitude of Environmental Impacts

Area of Impact	General Criteria Used to Define Descriptor Term		
	Negligible to Low	Moderate	Large
Human health and safety (construction, operations, transportation)	Human health and safety impacts are provided in terms of the number or degree of health effects (impacts are not described in terms of negligible to low, moderate, or large)		
Air quality	Air quality impacts are compared with applicable air standards or guidelines (impacts are not described in terms of negligible to low, moderate, or large)		
Surface water			
Runoff	No observable increase in runoff.	Increased runoff, but manageable through existing drainage patterns	Existing drainage patterns possibly inadequate to handle increased runoff.
Floodplains	No observable change in existing floodplains	Change in existing floodplain area of between 1% and 10%	Change in existing floodplain area of more than 10%
Water quality	Water quality impacts are compared with applicable water quality standards or guidelines (impacts are not described in terms of negligible to low, moderate, or large)		
Groundwater			
Recharge	No observable change in recharge	Observable change in volumetric flow of water reaching the groundwater aquifer, but less than a 50% change in the existing rate	Change in volumetric flow of water reaching the groundwater aquifer of more than 50%
Depth to groundwater	No observable change	Change of less than 10% from the current value	Change of more than 10% from the current value
Water quality	Water quality impacts are compared with water quality standards or guidelines (impacts are not described in terms of negligible to low, moderate, or large)		
Soil			
Topography	No observable change in elevations	Changes in elevation of less than 5 ft over the area impacted	Changes in elevation of more than 5 ft over the area impacted
Permeability	No observable change in infiltration	Changes of less than 50% in infiltration	Changes of more than 50% in infiltration
Erosion potential	No observable change in soil loss	Changes in soil loss of less than 50% of existing rate	Changes in soil loss of more than 50% of the existing rate
Soil quality	Soil quality impacts are compared with EPA guidelines (impacts are not described in terms of negligible to low, moderate, or large)		

TABLE 4.2 (Cont.)

Area of Impact	General Criteria Used to Define Descriptor Term		
	Negligible to Low	Moderate	Large
Socioeconomics			
Economic activity	Less than 0.1 percentage point increase in annual employment growth rate in the region of influence	Between 0.1 and 1.0 percentage point increase in annual employment growth rate in the region of influence	More than 1.0 percentage point increase in annual employment growth rate in the region of influence
Population	Less than 0.1 percentage point increase in annual population growth rate in the region of influence	Between 0.1 and 1.0 percentage point increase in annual population growth rate in the region of influence	More than 1.0 percentage point increase in annual population growth rate in the region of influence
Housing	Less than 20% of vacant housing units required in the region of influence	Between 20% and 50% of vacant housing units required in the region of influence	More than 50% of vacant housing units required in the region of influence
Public finance	Less than 1% increase in local jurisdictional revenues and expenditures	Between 1% and 5% increase in local jurisdictional revenues and expenditures	More than 5% increase in local jurisdictional revenues and expenditures
Ecology			
	No mortality of individual organisms; no measurable effects on population or community parameters; general guideline of less than 10 acres of habitat loss.	Mortality of a small number of individual organisms; short-term effects on population or community parameters; general guideline of between 10 and 100 acres of habitat loss	Mortality of a large number of individual organisms; long-term effects on population or community parameters; general guideline of more than 100 acres of habitat loss
Waste management	Little or no change in waste facility operations or capacity requirements (i.e., less than 10% increased waste loading or treatment/disposal capacity requirements)	Likely increase in capacity needed at existing facilities (i.e., increase of 10% to 100% in waste loading or treatment/disposal capacity requirements)	Change in waste facility(s) operations and need for increased capacity (i.e., increase of more than 100% in waste loading or treatment/disposal capacity requirements)
Resource requirements	Required quantities of commonly used materials for construction and operation of facilities less than 5% of existing local capacity; no use of uncommon materials such as Monel and Inconel	Required quantities of commonly used materials for construction and operation of facilities more than 5% of existing local capacity; use of small amounts of uncommon materials such as Monel and Inconel	Required quantities of commonly used materials for construction and operation of facilities more than 90% of existing local capacity; use of large amounts of uncommon materials such as Monel and Inconel

TABLE 4.2 (Cont.)

Area of Impact	General Criteria Used to Define Descriptor Term		
	Negligible to Low	Moderate	Large
Land use	No effect on land-use patterns and traffic flow; general guideline of land-use requirement of less than 50 acres	Land-use patterns affected; land conversion likely; traffic congestion at intersections during peak hours, with change in level-of-service rating; general guideline of land-use requirement of between 50 and 200 acres	Land-use patterns affected; land conversion in conflict with existing land-use plans and controls; traffic flow restricted, with congestion at intersections, with a high level-of-service rating; general guideline of land-use requirement of more than 200 acres
Cultural resources	Cultural resource criteria are not defined because potential impacts could not be ranked (either they would occur or would not occur) and were considered only in a site-specific context		
Environmental justice	Environmental justice criteria are not defined because potential impacts could not be ranked (either they would occur or would not occur) and were considered only in a site-specific context		

5 DESCRIPTION OF DISPOSAL FACILITY OPTIONS

This section provides a brief summary of the different disposal facility options considered in the assessment of depleted UF₄ disposal impacts. The information is based on preconceptual design data provided in the UF₄ engineering analysis report (Folga and Kier 2001). The engineering analysis report includes much more detailed information, such as descriptions of facility layouts and resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios.

The three disposal facility options considered are shallow earthen structures (engineered trenches), vaults, and an underground mine. The depleted UF₄ would be produced and packaged at a chemical conversion facility and shipped via truck or rail to the disposal site. For each option, it was assumed that the UF₄ would be packaged in either 30-gal (110-L) or 55-gal (208-L) drums. Two drum sizes were considered for two reasons: (1) to account for uncertainties in the actual packages that would be used if UF₄ were produced for disposal and (2) in recognition of the fact that the relatively large weight of a 55-gal drum loaded with UF₄ could pose handling problems at a disposal site. The properties and numbers of drums requiring disposal for the two depleted UF₆ inventories considered are summarized in Table 5.1.

A disposal facility for depleted UF₄ would consist of a disposal area and two major types of buildings:

1. *Warehouse for receiving and shipping products* — in which containers shipped to the disposal facility would be temporarily stored and then inspected and transported to a disposal unit. If the inspection were to show that a drum was defective, its contents would be repackaged (i.e., transferred to another drum) before being transferred to a disposal unit from the shipping part of the building. The damaged drums could be crushed and disposed of as LLW, or they could be decontaminated and recycled as scrap metal, if allowed by federal and state regulations at the time.
2. *Administration building* — that would incorporate all technical and administrative support functions needed to manage the operation of the disposal facility. These functions include security, facility access control, health physics and radiation badges, sanitary facilities, work control and personnel support, internal and external (public relations) communications, spill or emergency response provisions, analytical laboratory, environmental regulatory reporting, and records management for materials control and accountability (MC&A).

TABLE 5.1 Estimated Content and Number of UF₄ Containers Requiring Disposal

Drum Capacity (gal)	Weight of Drum Contents (metric tons)	Amount of Uranium per Drum (metric tons)	No. of Drums Required	
			For 500,000 Metric Tons of UF ₄	For 630,000 Metric Tons of UF ₄
30	0.364	0.276	1.373E+06	1.729E+06
55	0.667	0.504	0.749E+06	0.943E+06

Source: Folga and Kier (2001).

These buildings, which would be common to the three disposal options considered, are collectively called the central wasteform facility. The land areas required for the wasteform facility are summarized in Table 5.2.

The unique features of each disposal facility option are briefly described in Sections 5.1 through 5.3 (see Folga and Kier [2001] for details). Land use parameters for each of the three facility options are presented in Table 5.3 for 500,000 metric tons of UF₄ and in Table 5.4 for 630,000 metric tons of UF₄.

5.1 DISPOSAL IN SHALLOW EARTHEN STRUCTURES

Shallow earthen structures, commonly referred to as engineered trenches, are among the most commonly used forms of LLW disposal, especially in dry climates. Shallow earthen structures would be excavated to a depth of about 26 ft (8 m), with the length and width determined by site conditions and the annual volume of waste to be disposed of (see Tables 5.3 and 5.4).

Disposal in shallow earthen structures would consist of placing waste on a stable structural pad with barrier walls constructed of compacted clay. Clay would be used because it prevents walls from collapsing or caving in and presents a relatively impermeable barrier to waste migration. The waste containers (i.e., drums) would be tightly stacked three pallets high in the bottom of the structure with forklifts. Any open space between containers would be filled with earth, sand, gravel, or other similar material as each layer of drums was placed.

After the structure would be filled, a 6-ft-thick (2-m-thick) cap composed of engineered fill dirt and clay would be placed on top of it and compacted. The cap would be mounded at least 3 ft (1 m) above the local grade and sloped to minimize the potential for water infiltration.

TABLE 5.2 Site Land Parameters at the Wasteform Facility

Parameter	500,000 Metric Tons of UF ₄		630,000 Metric Tons of UF ₄	
	30-gal Drums	55-gal Drums	30-gal Drums	55-gal Drums
Site land area (ha)	1.7	1.4	1.7	1.4
Disturbed land area (ha)	1.7	1.4	1.7	1.4
Total fenced area (ha)	1.6	1.3	1.6	1.3
Total paved area (ha)	0.33	0.28	0.34	0.28
Total excavated material (m ³)	9,550	7,550	9,750	7,550

TABLE 5.3 Site Land Parameters for Disposal of 500,000 Metric Tons of UF₄

Parameter	Shallow Earthen Structure	Vaults	Mine
Disposal in 30-gal drums			
Site land area (ha)	20.6	25.4	236
Disturbed land area (ha)	18.7	25.4	236
Total fenced area (ha)	20.6	25.4	236
Total paved area (ha)	0.9	3.5	12
Total excavated material (m ³)	1.29E+06	5.71E+05	1.22E+06
Facility length (m)	597	552	1,586
Facility width (m)	344	460	1,560
Underground site land area (ha)	NA ^a	NA	247
Disposal in 55-gal drums			
Site land area (ha)	17.4	31.6	168
Disturbed land area (ha)	15.7	31.6	168
Total fenced area (ha)	17.4	31.6	168
Total paved area (ha)	0.8	4.4	11
Total excavated material (m ³)	1.06E+06	6.31E+05	9.91E+05
Facility length (m)	506	688	1,355
Facility width (m)	344	460	1,378
Underground site land area (ha)	NA	NA	187

^a NA = not applicable.

Source: Folga and Kier (2001).

TABLE 5.4 Site Land Parameters for Disposal of 630,000 Metric Tons of UF₄

Parameter	Shallow Earthen Structure	Vaults	Mine
Disposal in 30-gal drums			
Site land area (ha)	25.5	31.6	310
Disturbed land area (ha)	23.4	31.6	310
Total fenced area (ha)	25.5	31.6	310
Total paved area (ha)	1.0	4.4	12
Total excavated material (m ³)	1.65E+06	7.14E+05	1.44E+06
Facility length (m)	597	688	1,740
Facility width (m)	427	460	1,782
Underground site land area (ha)	NA ^a	NA	310
Disposal in 55-gal drums			
Site land area (ha)	21.6	37.9	220
Disturbed land area (ha)	19.7	37.9	220
Total fenced area (ha)	21.6	37.9	220
Total paved area (ha)	0.9	5.2	12
Total excavated material (m ³)	1.36E+06	7.89E+05	1.16E+06
Facility length (m)	506	824	1,509
Facility width (m)	427	460	1,548
Underground site land area (ha)	NA	NA	234

^a NA = not applicable.

Source: Folga and Kier (2001).

5.2 DISPOSAL IN VAULTS

Belowground vaults are subsurface reinforced concrete structures. For the preconceptual design basis, the vaults were assumed to be 131 ft (40 m) wide × 266 ft (81 m) long, with a height of approximately 20 ft (6 m). The concrete walls were assumed to be 1 ft (0.3 m) thick, with a floor slab thickness of 2 ft (0.6 m). The majority of the structure would be located underground, with only the roof area above grade.

Each vault was assumed to be divided into five sections, each section approximately 66 ft (20 m) long by 26 ft (8 m) wide and 13 ft (4 m) tall. As opposed to shallow earthen structures, the walls and floor of a vault would be constructed of reinforced concrete. A crane would be used to

place drums within each section. Once a vault would be full, any open space between containers would be filled with earth, sand, gravel, or other similar material. A permanent roof slab of reinforced concrete that would completely cover the vault would be installed after all five sections were filled. A cap of engineered fill dirt and clay would be placed on top of the concrete cover and compacted. The cap would be mounded above the local grade and sloped to minimize the potential for water infiltration.

5.3 DISPOSAL IN A MINE

An underground mine disposal facility would be a repository for permanent deep geological disposal. A mine disposal facility could either use a previously existing mine or be constructed for the sole purpose of waste disposal. For purposes of comparing options, the conservative assumption of constructing a new mine was assessed for this analysis. A mine disposal facility would consist of surface facilities that would provide space for waste receiving and inspection (the wasteform facility) and of shafts and ramps that would provide access to and ventilation of the underground portion of the repository.

The underground portion would consist of tunnels (called “drifts”) for the transport and disposal of waste underground. The dimensions of the drifts were assumed to be 21 ft (6.5 m) wide × 330 ft (100 m) long and 18 ft (5 m) high. Waste containers would be placed in drifts, and the drifts would be backfilled with loose material after emplacement.

6 IMPACTS OF OPTIONS — OPERATIONAL PHASE

Potential impacts analyzed for the operational phase of the depleted UF₄ disposal facility options included impacts occurring during facility construction and during the period when the waste material would be actively placed into disposal units (20 years for disposal of 500,000 metric tons of UF₄; 25 years for disposal of 630,000 metric tons of UF₄). The potential environmental impacts during the post-closure period, after the disposal facility would cease operations, are presented in Section 7; transportation impacts are presented in Section 8. The estimated operational impacts are discussed in this section for each area of impact.

The environmental impacts during the operational phase were evaluated on the basis of the information described in the UF₄ engineering analysis report (Folga and Kier 2001). The following general assumptions apply to the assessment of impacts:

- C Impacts during the operational phase include those from preliminary facility construction and the period when UF₄ would be actively placed into disposal units. Construction of disposal units would occur incrementally while waste material was being received.
- C Bulk (ungrouted) UF₄ would be disposed of directly without significant processing at the disposal facility. Consequently, essentially no UF₄ air or water emissions would be associated with normal (nonaccident) operations. Emissions would include dust during construction and exhaust emissions from equipment used during construction and waste emplacement.
- C The potential impacts from disposal were analyzed for a generic dry environmental setting. The historical meteorological conditions for five actual dry locations in the southwestern United States were used for dispersion calculations. It was assumed that a disposal facility would be located in a rural area with a population density of 15 persons/mi² (6 persons/km²).

6.1 HUMAN HEALTH — NORMAL OPERATIONS

6.1.1 Radiological Impacts

Radiological impacts during normal operations of the facility were estimated for involved workers, noninvolved workers, and members of the general public. External radiation resulting from the handling and shipping of uranium materials would be the major source of exposure for involved

workers. Variations in exposures for the three disposal types considered (shallow earthen structures, vaults, or mine) would be caused by different practices employed for emplacement in the three different types of disposal facilities. Disposal in a mine would require transport of waste containers from the ground surface to the underground cavities, whereas disposal in shallow earthen structures and vaults would require filling and capping efforts to cover the waste containers with dirt, cement, and/or other engineering materials. Variations in the results for 30-gal drums and 55-gal drums would be caused by different dose rates due to different sizes of containers and different numbers of containers to be handled. In general, the average radiation exposure to involved workers would be less than 650 mrem/yr.

Exposures to noninvolved workers and the general public could result if there were releases of uranium compounds to the atmosphere or surface water. However, during normal operations, no releases would be expected (Folga and Kier 2001); therefore, potential exposures would be zero for these two groups of receptors.

The estimated potential radiation exposures for the different disposal options are listed in Table 6.1. The risk of latent cancer fatalities (LCFs) resulting from the exposures presented in Table 6.1 are presented in Table 6.2. The risks presented in Table 6.2 were estimated by multiplying the radiation LCF doses by health risk conversion factors of 4×10^{-4} LCF/person-rem for workers and 5×10^{-4} LCF/person-rem for members of the public. Detailed discussions of the methodology used in the radiological impact analyses are provided in Appendix C of the PEIS (DOE 1999) and Cheng et al. (1997).

6.1.1.1 Disposal of 500,000 Metric Tons of UF₄

The estimated radiation exposures to involved workers from disposal of UF₄ in 55-gal drums would be somewhat greater than the radiation exposures from disposal of UF₄ in 30-gal drums. Annual collective doses would range from 14 to 18 person-rem/yr for disposal in 30-gal drums and from 16 to 20 person-rem/yr in 55-gal drums. These collective doses would result in less than 1×10^{-2} fatalities per year (1 additional latent cancer fatality [LCF] in 100 years).

Estimated average worker doses for disposal in 30 gal-drums would range from 260 to 440 mrem/yr. For disposal in 55-gal drums, the average doses would range from 410 mrem/yr to 650 mrem/yr. Potential exposures of involved workers would be well below the radiation dose limit of 5,000 mrem/yr (*Code of Federal Regulations*, Title 10, Part 835 [10 CFR Part 835]).

In general, greater radiation exposures would be expected from disposal in a mine than from disposal in shallow earthen structures or vaults. For the latter two disposal technologies, radiation exposures would be about the same.

TABLE 6.1 Estimated Radiological Doses from Normal Operations under UF₄ Disposal Options

Option/Inventory ^a	Annual Dose to Receptor					
	Involved Worker ^b		Noninvolved Worker ^c		General Public ^d	
	Average Individual Dose (mrem)	Collective Dose (person-rem)	MEI Dose (mrem)	Collective Dose (person-rem)	MEI Dose (mrem)	Collective Dose (person-rem)
<i>Disposal of 500,000 Metric Tons of UF₄</i>						
Shallow earthen structure						
30-gal drums	260	14	0	0	0	0
55-gal drums	410	16	0	0	0	0
Vault						
30-gal drums	260	14	0	0	0	0
55-gal drums	410	16	0	0	0	0
Mine						
30-gal drums	440	18	0	0	0	0
55-gal drums	650	20	0	0	0	0
<i>Disposal of 630,000 Metric Tons of UF₄</i>						
Shallow earthen structure						
30-gal drums	260	14	0	0	0	0
55-gal drums	410	16	0	0	0	0
Vault						
30-gal drums	260	14	0	0	0	0
55-gal drums	410	16	0	0	0	0
Mine						
30-gal drums	440	18	0	0	0	0
55-gal drums	650	20	0	0	0	0

^a Two inventories were considered for each option: 500,000 and 630,000 metric tons of UF₄. The first inventory is a result of converting 560,000 metric tons of depleted UF₆ that DOE facilities had generated in the past. The second inventory is a result of converting 705,000 metric tons of UF₆ that included both the amount DOE generated and the amount USEC generated.

^b Involved workers are those workers directly involved in handling 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 (DOE 1992).

^c Noninvolved workers are individuals who do not participate in material handling activities, such as employees in the administration building. The number of noninvolved workers ranges from about 15 when disposal is in shallow earthen structures to about 30 when disposal is in vaults or mine cavities.

^d The off-site general public is defined as residents who live within a radius of 50 mi (80 km) around the disposal site.

TABLE 6.2 Estimated Latent Cancer Fatality Risks from Normal Operations under UF₄ Disposal Options

Option/Inventory ^a	Annual Risk to Receptor					
	Involved Worker ^b		Noninvolved Worker ^c		General Public ^d	
	Average Risk (risk)	Collective Risk (fatalities)	MEI Risk (risk)	Collective Risk (fatalities)	MEI Risk (risk)	Collective Risk (fatalities)
Disposal of 500,000 Metric Tons of UF₄						
Shallow earthen structure						
30-gal drums	1×10^{-4}	6×10^{-3}	0	0	0	0
55-gal drums	2×10^{-4}	6×10^{-3}	0	0	0	0
Vault						
30-gal drums	1×10^{-4}	6×10^{-3}	0	0	0	0
55-gal drums	2×10^{-4}	6×10^{-3}	0	0	0	0
Mine						
30-gal drums	2×10^{-4}	7×10^{-3}	0	0	0	0
55-gal drums	3×10^{-4}	8×10^{-3}	0	0	0	0
Disposal of 630,000 Metric Tons of UF₄						
Shallow earthen structure						
30-gal drums	1×10^{-4}	6×10^{-3}	0	0	0	0
55-gal drums	2×10^{-4}	6×10^{-3}	0	0	0	0
Vault						
30-gal drums	1×10^{-4}	6×10^{-3}	0	0	0	0
55-gal drums	2×10^{-4}	6×10^{-3}	0	0	0	0
Mine						
30-gal drums	2×10^{-4}	7×10^{-3}	0	0	0	0
55-gal drums	3×10^{-4}	8×10^{-3}	0	0	0	0

^a Two inventories were considered for each option: 500,000 and 630,000 metric tons of UF₄. The first inventory is a result of converting 560,000 metric tons of UF₆ that DOE facilities had generated in the past. The second inventory is a result of converting 705,000 metric tons of UF₆ that included both the amount DOE generated and the amount USEC generated.

^b Involved workers are those workers directly involved in handling materials. Impacts are presented as average individual risk and collective risk for the worker population.

^c Noninvolved workers are individuals who do not participate in material handling activities, such as employees in the administration building. The number of noninvolved workers ranges from about 15 when disposal is in shallow earthen structures to about 30 when disposal is in vaults or mine cavities.

^d The off-site general public is defined as residents who live within a radius of 50 mi (80 km) around the disposal site.

6.1.1.2 Disposal of 630,000 Metric Tons of UF₄

Although the inventory of depleted UF₄ would increase from 500,000 to 630,000 metric tons, the annual radiation exposures for the receptors considered would be the same as that reported in Section 6.1.1.1. This is because the amount of UF₄ that would be handled per year is assumed to be the same for both cases. However, cumulative exposures from the entire operational period would be greater for disposal of 630,000 metric tons than for disposal of 500,000 metric tons because the operational period would increase from 20 to 25 years.

6.1.2 Chemical Impacts

Chemical impacts to the general public, noninvolved workers, and involved workers during the operational phase of the depleted UF₄ disposal facility were considered. The only reasonable waste form option considered for depleted UF₄ disposal was the ungrouted form, which would be packaged at the conversion facility. Therefore, no chemical impacts to the general public or noninvolved workers would occur at the disposal facility, because airborne emissions would not be expected (Folga and Kier 2001).

For involved workers, the only potential exposures would occur from repackaging the small number of drums that would require it as a result of handling damage. The engineering analysis report (Folga and Kier 2001) states that approximately 25 drums would require repackaging annually, whether disposal was in 30-gal or 55-gal drums. For drum repackaging, electrically powered transfer equipment would pour the contents of the damaged drums into new drums, minimizing worker contact with the drum contents. The transfer equipment would operate in such a way as to keep the operation enclosed and eliminate UF₄ dust generation. Therefore, exposure of involved workers to UF₄ dust would be very low and well below occupational exposure standards.

6.2 HUMAN HEALTH — ACCIDENT CONDITIONS

A range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents was considered in the UF₄ engineering analysis report (Folga and Kier 2001). These accidents are listed in Table 6.3. The following sections present the results for radiological and chemical health impacts of the highest consequence accident in each frequency category considered. Detailed descriptions of the methodology and assumptions used in these calculations are provided in Appendix C of the PEIS and Policastro et al. (1997).

TABLE 6.3 Accidents Considered under UF₄ Disposal Options^a

Option/Accident Scenario	Accident Description	Chemical Form	Amount Released (lb)	Duration (min)	Release Level
<i>Likely Accidents (frequency: 1 or more times in 100 years)</i>					
Mishandling/drop of drum inside the product receiving area	A single UF ₄ drum is damaged by a forklift and spills its contents onto the ground inside the product receiving area.	UF ₄	0.000079 (0.00015)	Puff	Stack
Mishandling/drop of drum outside the product receiving area	A single UF ₄ drum is damaged by a forklift and spills its contents outside the product receiving area.	UF ₄	0.079 (0.15)	Puff	Ground
<i>Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)</i>					
Earthquake	The product receiving area is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	UF ₄	275 (275)	Puff	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the product receiving area structures and confinement systems.	UF ₄	275 (275)	Puff	Ground
<i>Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)</i>					
Fire/explosion inside the product receiving and shipping warehouse	A fire or explosion within the product receiving and shipping warehouse affects the contents of a single pallet of four drums.	UO ₂	0.0029 (0.0051)	Puff	Stack
		HF	8.64		
<i>Incredible Accidents (frequency: less than 1 in 1 million years)</i>					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA ^b	NA	NA

^a The amount released is presented for 30-gal drums; results for 55-gal drums are presented in parentheses.

^b NA = not applicable.

As they were in the PEIS, accident impacts were calculated for both noninvolved workers and members of the public within 50 mi (80 km) of the disposal facility. Chemical and radiological exposures for involved workers (those within 100 m of the release) under accident conditions would depend on how rapidly the accident developed, the exact location and response of the workers, the direction and amount of the release, the physical forces causing or caused by the accident, meteorological conditions, and characteristics of the room or building if the accident occurred indoors. Impacts to involved workers under accident conditions would likely be dominated by physical forces from the accident itself, so that quantitative dose/effect estimates would not be meaningful. For these reasons, the impacts to involved workers during accidents were not quantified.

However, it is recognized that injuries and fatalities among involved workers would be possible if an accident did occur.

6.2.1 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 6.4. The LCF risks for these accidents are given in Table 6.5. The doses and the risks are presented as ranges (maximum and minimum) because two different meteorological conditions (stable and unstable) were evaluated for each disposal option. The doses and risks presented here were obtained by assuming that the accidents would occur. The results are independent of the overall throughput of the disposal facility because the accidents involve only a limited amount of material that would be at risk. 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 single year. The following conclusions may be drawn from the radiological health impact results:

- C No cancer fatalities from radiation doses would be expected from any of the accidents.
- C The maximum radiological dose to noninvolved worker and general public maximally exposed individuals (MEIs) (assuming an accident occurred) would be 5.1 rem. This dose is less than the 25-rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the U.S. Nuclear Regulatory Commission (NRC 1994b).
- C The overall radiological risk to worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table 6.5] by the annual probability of occurrence by the number of years of operations) would be much less than 1 for all of the disposal accidents.

6.2.2 Chemical Impacts

The accidents assessed in this section were those listed in Table 6.3. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables 6.6 and 6.7. Results are presented as (1) number of people with the potential for adverse effects and (2) number of people with the potential for irreversible adverse effects. The tables present the results for the accident within each frequency category that would affect the largest number of people (total of noninvolved workers and off-site population) (Policastro et al. 1997). The number of workers and

TABLE 6.4 Estimated Radiological Doses per Accident Occurrence under UF₄ Disposal Options

Option/Accident ^a	Frequency Category ^b	Maximum Dose ^c				Minimum Dose ^c			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Disposal in 30-gal drums									
Mishandling/drop of drum outside	L	2.6×10^{-5}	2.3×10^{-6}	8.2×10^{-7}	4.8×10^{-6}	2.6×10^{-5}	2.3×10^{-6}	6.3×10^{-7}	4.8×10^{-6}
Tornado	U	5.1	2.2×10^{-1}	3.9×10^{-2}	5.1×10^{-2}	4.7×10^{-1}	3.8×10^{-2}	1.0×10^{-2}	3.1×10^{-2}
Fire or explosion inside the product receiving and shipping warehouse	EU	9.6×10^{-8}	1.9×10^{-7}	9.9×10^{-8}	3.8×10^{-6}	2.9×10^{-11}	5.4×10^{-11}	4.9×10^{-9}	1.7×10^{-6}
Disposal in 55-gal drums									
Mishandling/drop of drum outside	L	4.8×10^{-5}	4.3×10^{-6}	1.5×10^{-6}	8.9×10^{-6}	4.8×10^{-5}	4.3×10^{-6}	1.2×10^{-6}	8.9×10^{-6}
Earthquake	U	5.1	2.2×10^{-1}	3.9×10^{-2}	5.1×10^{-2}	4.7×10^{-1}	3.8×10^{-2}	1.0×10^{-2}	3.1×10^{-2}
Fire or explosion inside the product receiving and shipping warehouse	EU	1.5×10^{-7}	2.9×10^{-7}	1.5×10^{-7}	5.8×10^{-6}	4.4×10^{-11}	8.3×10^{-11}	7.4×10^{-9}	2.7×10^{-6}

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

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

^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 6.5 Estimated Radiological Health Risks per Accident Occurrence under UF₄ Disposal Options^a

Option/Accident ^b	Frequency Category ^c	Maximum Risk ^d (LCF)				Minimum Risk ^d (LCF)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI	Population	MEI	Population	MEI	Population	MEI	Population
Disposal in 30-gal drums									
Mishandling/drop of drum outside	L	1×10^{-8}	9×10^{-10}	4×10^{-10}	2×10^{-9}	1×10^{-8}	9×10^{-10}	3×10^{-10}	4×10^{-9}
Tornado	U	2×10^{-3}	9×10^{-5}	2×10^{-5}	3×10^{-5}	2×10^{-4}	2×10^{-5}	5×10^{-6}	2×10^{-5}
Fire or explosion inside the product receiving and shipping warehouse	EU	4×10^{-11}	8×10^{-11}	5×10^{-11}	2×10^{-9}	1×10^{-14}	2×10^{-14}	2×10^{-12}	9×10^{-10}
Disposal in 55-gal drums									
Mishandling/drop of drum outside	L	2×10^{-8}	2×10^{-9}	8×10^{-10}	4×10^{-9}	2×10^{-8}	2×10^{-9}	6×10^{-10}	4×10^{-9}
Earthquake	U	2×10^{-3}	9×10^{-5}	2×10^{-5}	3×10^{-5}	2×10^{-4}	2×10^{-5}	5×10^{-6}	2×10^{-5}
Fire or explosion inside the product receiving and shipping warehouse	EU	6×10^{-11}	1×10^{-10}	8×10^{-11}	3×10^{-9}	2×10^{-14}	3×10^{-14}	4×10^{-12}	1×10^{-9}

^a Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCF) times the estimated frequency times 20 years of operations (25 years for disposal of 630,000 metric tons of UF₄). The estimated frequencies are as follows: likely (L) = 0.1; unlikely (U) = 0.001; extremely unlikely (EU) = 0.00001; incredible (I) = 0.000001.

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

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

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

TABLE 6.6 Number of Persons with Potential for Adverse Effects from Chemical Exposures from Accidents under UF₄ Disposal 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
Disposal as ungrouted UF ₄									
Mishandling/drop of drum outside ^f	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes	2.6	Yes ^g	2.5	Yes	3.5	No	0.4
Fire or explosion inside ^f	EU	No	0	No	0	No	0	No	0

^a Values shown are the consequences if the accident did occur. Consequences are the same for disposal in 30-gal drums and disposal in 55-gal drums. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations (25 years for disposal of the 705,000 metric tons of UF₆ inventory). The estimated frequencies are as follows: likely (L) = 0.1; unlikely (U) = 0.001; extremely unlikely (EU) = 0.00001; incredible (I) = 0.000001.

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

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

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

^e At the MEI location, the determination is either “Yes” or “No” for potential adverse effects to an individual.

^f These accidents would result in the largest plume sizes, although no people would be affected.

^g MEI locations were evaluated at 100 m from ground-level releases for noninvolved workers and at the location of highest off-site concentration for members of the general public.

TABLE 6.7 Number of Persons with Potential for Irreversible Adverse Effects from Chemical Exposures from Accidents under UF₄ Disposal 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
Disposal as Ungrouned UF ₄									
Mishandling/drop of drum outside ^f	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes	2.3	Yes ^g	0.8	Yes	2.7	No	0.1
Fire or explosion inside ^f	EU	No	0	No	0	No	0	No	0

^a Values shown are the consequences if the accident did occur. Consequences are the same for disposal in 30-gal drums and disposal in 55-gal drums. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations (25 years for disposal of the 705,000 metric tons of UF₆ inventory). The estimated frequencies are as follows: likely (L) = 0.1; unlikely (U) = 0.001; extremely unlikely (EU) = 0.00001; incredible (I) = 0.000001.

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

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

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

^e At the MEI location, the determination is either “Yes” or “No” for potential irreversible adverse effects to an individual.

^f These accidents would result in the largest plume sizes, although no people would be affected.

^g MEI locations were evaluated at 100 m from ground-level releases for noninvolved workers and at the location of highest off-site concentration for members of the general public.

number of members of the off-site public represent the impacts if the associated accident was assumed to occur. These impacts may be summarized as follows:

- C If the accidents identified in Table 6.3 did occur, the number of persons in the off-site general population with the potential for adverse effects and irreversible adverse effects would range from 0 to 1 (MEI), the maximum corresponding to an earthquake accident. The number of noninvolved workers with the potential for adverse effects would range from 3 to 4 and with the potential for irreversible adverse effects would range from 2 to 3, the maximums corresponding to an earthquake accident.
- C There would be no difference in the consequences from an accident associated with disposal in shallow earthen structures, vaults, or a mine.
- C The largest impacts would be caused by an earthquake in the product receiving area. Accidents involving stack emissions would have smaller impacts when compared with accidents involving releases at ground level because of the larger dilution (and lower source terms) involved with the stack emissions.
- C For the earthquake accident, the noninvolved worker and the public MEIs could have the potential for both adverse effects and irreversible adverse effects. For all other accidents, the worker and general public MEIs would not have the potential for adverse effects or irreversible adverse effects.
- C The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (20 years for disposal of 500,000 metric tons of UF₄; 25 years for disposal of 630,000 metric tons of UF₄). The results indicated that the maximum risk values would be less than 1 for all accidents. These risk values are conservative because the numbers of people affected were based on assuming meteorological conditions that would result in the maximum reasonably foreseeable plume size (i.e., F stability and 1 m/s wind speed).

To aid in the interpretation of accident analysis results, the number of fatalities that could be associated with the estimated potential irreversible adverse effects was estimated. The bounding case accidents shown in Table 6.7 would involve releases of UF₄ and potential exposure to uranium compounds. If the accident occurred, exposures would be expected to result in death to 1% or fewer of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Thus, for noninvolved workers and members of the general public experiencing a range of 0 to 1 irreversible adverse effects, 0 deaths would be expected.

6.2.3 Physical Hazards

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

The annual fatality rates used were 15 per 100,000 workers for construction and 4 per 100,000 workers for operations. The annual injury rates used were 5.5 per 100 workers for construction and 5.3 per 100 workers for operations. More recent injury statistics released in 1999 show that fatality and injury rates have decreased slightly (National Safety Council 1999). The updated annual fatality rates would be 13.9 per 100,000 workers for construction and 3.2 per 100,000 workers for operations. The updated annual injury rates would be 4.4 per 100 workers for construction and 4.8 per 100 workers for operations. Because these changes are minor and in order to maintain comparability with the disposal impacts published in the PEIS, the more recent fatality and injury rates were not used for this assessment.

Fatality risks for all options were less than 1 fatality. However, both fatality and injury risks from mining options were two times or more greater than those from shallow earthen structure or vault options. The risks for the mine options were almost twice as large as the risks for the other options, mainly because of the increased risk associated with construction of the large mine that would be needed for the entire inventory of UF₄. Mitigation of risks from construction, loading, and closure of mines can be accomplished to a certain extent by instituting safety measures and by conducting thorough safety training programs for personnel.

Estimated fatalities ranged from 0.13 to 0.76, and injury incidences ranged from 88 to 347 (see Table 6.8). Except for the mine disposal option discussed above, the other options were fairly comparable with respect to predicted fatalities and injuries resulting from physical trauma.

6.3 AIR QUALITY

The methodology used to analyze air quality impacts from disposal options is described in Appendix C of the PEIS and Tschanz (1997). Pollutant concentrations were estimated at several distances from the center of the facility because the size and location of the generic disposal facility are uncertain.

Pollutant emissions would result from construction of the wasteform facility and construction of the disposal areas/facilities. The annual emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM₁₀) with

TABLE 6.8 Potential Impacts on Human Health from Physical Hazards from Accidents under UF₄ Disposal Options

UF ₄ Disposal Option	Impacts to All Disposal Facility Workers ^a					
	Fatality Incidence ^b			Injury Incidence ^b		
	Wasteform Facility	Disposal Facility	Total	Wasteform Facility	Disposal Facility	Total
<i>500,000 Metric Tons UF₄ in 30-gal Drums</i>						
Shallow earthen structure	0.07	0.09	0.16	58	47	105
Vault	0.07	0.18	0.25	58	100	158
Mine	0.07	0.59	0.66	59	241	300
<i>500,000 Metric Tons UF₄ in 55-gal Drums</i>						
Shallow earthen structure	0.06	0.07	0.13	47	41	88
Vault	0.06	0.17	0.23	47	91	138
Mine	0.06	0.53	0.59	48	214	262
<i>630,000 Metric Tons UF₄ in 30-gal Drums</i>						
Shallow earthen structure	0.08	0.09	0.17	69	54	123
Vault	0.08	0.20	0.28	69	118	187
Mine	0.08	0.68	0.76	70	277	347
<i>630,000 Metric Tons UF₄ in 55-gal Drums</i>						
Shallow earthen structure	0.07	0.08	0.15	57	46	103
Vault	0.07	0.21	0.28	57	109	166
Mine	0.07	0.59	0.66	59	237	296

^a Values are rounded to two significant figures. All construction and operations workers at the disposal facilities were included in the physical hazard risk calculations.

^b Fatality incidence and injury incidence were calculated as the number of full-time-equivalent employees times the annual fatality rate times the number of years. Only injuries involving lost workdays were included. Injury and fatality incidence rates used in the calculations were taken from National Safety Council (1995).

a mean aerodynamic diameter of 10 μ m or less, resulting from construction of the wasteform facility and from construction of disposal areas/facilities, are shown in Table 6.9 for disposal of 630,000 metric tons of UF₄ in 30-gal drums. The criteria pollutant emissions from construction and operation of the other disposal facilities are related to those in Table 6.9 by the scaling factors listed in Table 6.10. Scaling factors for non-PM₁₀ (CO, HC, NO_x) and PM₁₀ pollutants are quite different; thus, scaling factors are listed separately in Table 6.10 for these two categories. For example, the CO emissions from operations involving the disposal of 630,000 metric tons of UF₄ in 30-gal drums in vaults would be 2.91×1.18 tons/yr, or 3.43 tons/yr. For the same option, the PM₁₀ emissions would be 0.039×22.7 tons/yr, or 0.89 ton/yr.

The highest concentration increments were estimated on the basis of the highest emissions for each of the construction and operation phases. In general, fugitive dust emissions, resulting from soil excavation and earth-moving activities, would be predominant over other criteria pollutants during the construction period. Potential air quality impacts were estimated on the basis of the highest PM₁₀ emissions (28.60 tons/yr or 25.95 metric tons/yr) from the construction of facilities: mines for disposal of 630,000 metric tons of UF₄ in 30-gal drums (as shown in the upper part of Table 6.11). At a distance of 2,460 ft (750 m) from the release point, the maximum 24-hour and annual PM₁₀ concentration increments during construction might be as large as 27% of the 150- μ g/m³ standard and 13% of the 50- μ g/m³ standard. Concentration increments would be much lower at the potential nearest residence, which is generally far from the site boundaries. The concentration increments for the other criteria pollutants (CO, SO_x, and NO_x) and HC would be 0.068, 0.32, 0.021, and 0.026 times as large, respectively, as those for PM₁₀. Because the other criteria pollutant concentration increments would be a smaller fraction of their standards than PM₁₀ would be, ambient air quality impacts associated with construction would be minor.

TABLE 6.9 Pollutant Emissions from Construction Activities Associated with Disposal Facilities for 630,000 Metric Tons of UF₄ Disposed of in 30-Gallon Drums

Pollutant	Pollutant Emissions from Construction (tons/yr)			
	Wasteform Facility	Shallow Earthen Structure	Vault	Mine
CO	0.801	2.60	1.18	1.96
HC	0.305	0.988	0.452	0.75
NO _x	3.71	12.1	5.46	9.11
SO _x	0.244	0.792	0.363	0.60
PM ₁₀	6.07	17.0	22.7	28.6

TABLE 6.10 Scaling Factors for Criteria Pollutant Emissions from Construction and Operations under UF₄ Disposal Options, Relative to Emissions from Construction Associated with Disposal Facilities for 630,00 Metric Tons of UF₄ Disposed of in 30-Gallon Drums

UF ₄ Disposal Option	Inventory Amount (metric tons)	Drum Size (gal)	Scaling Factors			
			Construction		Operations	
Wasteform facility	630,000	30	1.00	(1.00) ^a	0.012	(5.3E-04) ^a
	630,000	55	0.76	(0.80)	0.011	(4.7E-04)
	500,000	30	0.98	(0.98)	0.012	(5.2E-04)
	500,000	55	0.76	(0.80)	0.011	(4.7E-04)
Shallow earthen structure	630,000	30	1.00	(1.00)	1.01	(0.040)
	630,000	55	0.55	(0.84)	0.56	(0.022)
	500,000	30	0.99	(0.80)	1.01	(0.040)
	500,000	55	0.55	(0.67)	0.56	(0.022)
Vault	630,000	30	1.00	(1.00)	2.91	(0.039)
	630,000	55	1.11	(1.20)	3.23	(0.043)
	500,000	30	1.00	(0.80)	2.91	(0.039)
	500,000	55	1.11	(1.00)	3.23	(0.043)
Mine	630,000	30	1.00	(1.00)	0.082	(1.17E-03)
	630,000	55	0.80	(0.81)	0.055	(7.83E-04)
	500,000	30	0.84	(0.85)	0.082	(7.41E-04)
	500,000	55	0.67	(0.69)	0.055	(4.97E-04)

^a Scaling factors for PM₁₀ are in parentheses.

Except for NO_x emissions from construction, NO_x emissions from engine exhaust and building space heating during operations would be the largest of all criteria pollutants. Potential air quality impacts were estimated on the basis of the highest NO_x emissions (17.62 tons/yr or 15.98 metric tons/yr) from facility operations: vaults for disposal of the original or new inventory in 55-gal drums (as shown in the lower part of Table 6.11). At a distance of 2,460 ft (750 m) from the release point, the maximum annual NO_x concentration increments during operation might be as large as 11% of the 100-: g/m³ standard. The other concentration increments for the criteria pollutant (CO, SO_x, and PM₁₀) and HC emissions would be 0.22, 0.067, 0.055, and 0.083 times as large, respectively, as those for NO_x. Because the impacts of all of these other pollutants relative to their standards would be less than that of NO_x, potential air quality impacts associated with operations would be minor.

TABLE 6.11 Maximum Concentrations at Three Receptor Distances Resulting from the Construction of a Mine and from the Operation of Vaults

Distance from Emitter to Receptor (m) in Dry Setting	Maximum Concentration (: g/m ³)				
	1-h Avg	3-h Avg	8-h Avg	24-h Avg	Annual Avg
Construction ^a					
750	470–500	170–200	79–110	32–41	3.8–6.7
1,000	380–410	150–180	64–85	25–32	2.4–4.4
1,500	270–280	85–100	41–56	16–20	1.3–2.3
Operations ^b					
750	300–490	110–240	50–130	21–55	2.3–11
1,000	240–370	96–160	42–86	16–33	1.5–4.3
1,500	170–230	55–81	26–48	10–19	0.76–1.5

^a Based on PM₁₀ emissions from 630,000 metric tons of UF₄ in 30-gal drums in a mine.

^b Based on NO_x emissions from 630,000 metric tons of UF₄ in 55-gal drums in a vault.

Construction and operations would occur simultaneously for the vault and shallow earthen structure disposal options. (Construction for the mined cavity option would occur before operations.) The combined construction and operations emissions might result in no increase in PM₁₀ emissions and a maximum increase of 38% in NO_x emissions over maximum operation emissions. Accordingly, the maximum combined construction and operations emissions might result in annual NO_x concentration increment as large as 15 : g/m³ at 2,460 ft (750 m), which is still well below the 100 : g/m³ standard.

Uranium emissions associated with operation of the wasteform facility would be expected to be negligible because there would be no uranium processing under normal conditions.

No quantitative estimate was made of the impacts on ozone conditions. Ozone formation is a regional issue; it is affected by emissions in the entire area around a proposed site. The pollutants most relevant to ozone formation that would result from the disposal of depleted uranium oxide are HC and NO_x. Later studies that would be conducted after specific technologies and sites have been selected could evaluate the potential effects that the release of those pollutants at a proposed site would have on ozone by comparing those releases with the total emissions of HC and NO_x in the surrounding area. Small additional contributions to the regional totals would be unlikely to alter the ozone attainment status of the region.

6.4 WATER AND SOIL

Because this disposal analysis is based on a generic site without a specified location or detailed description, potential impacts to surface water, groundwater and soil could not be assessed on a site-specific basis. Nevertheless, the relative impacts would have the same ranking as that for resource needs. Tables 6.12 through 6.15 summarize the resource requirements for constructing and operating the wasteform facility, shallow earthen structure disposal facility, vault disposal facility, and mined-cavity disposal facility, respectively. Examination of these data indicates that the ranking of facilities (largest to smallest) on the basis of resource requirements would be as follows: mine, vault, shallow earthen structure, and wasteform facility. For each facility, a secondary ranking indicates that the resources required for disposal would be consistently larger for more UF₄ (630,000 versus 500,000 metric tons) and smaller containers (30 versus 55 gallons). Therefore, construction and operation of a mine would have the greatest potential for affecting water and soil; construction and operation of the shallow earthen structure would have the least.

If the disposal facility was located on a site that was large compared with the size of the facility, and if it was near a river having a minimum flow that was large compared with annual water use and wastewater discharge, impacts on surface water, groundwater, and soil would be negligible. The reason is because a large site and large river could sufficiently buffer the resources to mitigate the effects produced by construction and operation of the facility.

On the other hand, if the site or the minimum flow in the river was small relative to the resource requirements, impacts would be larger. For example, if the minimum flow in the river was 500 gal/min or gpm, the net annual water withdrawal for operation of the wasteform facility that disposes of 630,000 metric tons of UF₄ in 30-gal containers would be about 10% of the flow. The impact of this relative withdrawal could produce moderate impacts to existing floodplains. Similarly, if the mine disposal facility was located on a 1,000-ha (247-acre) site, moderate to large impacts on soil permeability and erosion could result.

More detailed calculations would be performed in the next tier of analyses once a disposal facility option would be selected. In general, impacts could be minimized by constructing and operating a facility that would have the smallest resource requirements as compared with available resources.

TABLE 6.12 Environmental Parameters for the Wasteform Facility

Parameter	30-gal Drums	55-gal Drums
<i>Disposal of 500,000 Metric Tons of UF₄</i>		
Land area (ha)	1.7	1.4
Disturbed area (ha)	1.7	1.4
Water		
Construction (10 ⁶ L)	3.3	2.7
Operations (10 ⁶ L/yr)	0.62	0.52
Wastewater		
Construction (m ³)	4,300	3,100
Operations (m ³ /yr)	986	859
Excavated material (m ³)	9,550	7,550
<i>Disposal of 630,000 Metric Tons of UF₄</i>		
Land area (ha)	1.7	1.4
Disturbed area (ha)	1.7	1.4
Water		
Construction (10 ⁶ L)	3.4	2.7
Operations (10 ⁶ L/yr)	0.63	0.52
Wastewater		
Construction (m ³)	4,400	3,100
Operations (m ³ /yr)	988	860
Excavated material (m ³)	9,750	7,550

6.5 SOCIOECONOMICS

The socioeconomic impacts of each UF₄ disposal option are discussed here for the peak year of construction and first year of operations. Impacts from each facility are presented separately. However, because the wasteform facility would process waste at the disposal site for each disposal option, the total impact can be determined by summing the impact of the wasteform facility and the impact of each separate facility option.

The impacts from each disposal option for disposal of both the 500,000 and the 630,000 metric tons of UF₄ in both container sizes on direct employment and income are shown in Table 6.16. Construction of a wasteform facility for disposal of the 500,000 metric tons of UF₄ in 30-gal containers would create 110 direct jobs and \$4.2 million in direct income. Disposal in 55-gal containers would create 80 direct jobs and \$2.9 million in direct income. Operation of the wasteform

TABLE 6.13 Environmental Parameters for a Shallow Earthen Structure

Parameter	30-gal Drums	55-gal Drums
<i>Disposal of 500,000 Metric Tons of UF₄</i>		
Land area (ha)	20.6	17.4
Disturbed area (ha)	18.7	15.7
Water		
Construction (10 ⁶ L)	0.28	0.27
Operations (10 ⁶ L/yr)	0.083	0.052
Wastewater		
Construction (m ³)	6,600	6,400
Operations (m ³ /yr)	NA ^a	NA
Excavated material (m ³)	1.29 × 10 ⁶	1.06 × 10 ⁶
<i>Disposal of 630,000 Metric Tons of UF₄</i>		
Land area (ha)	25.5	21.6
Disturbed area (ha)	23.4	19.7
Water		
Construction (10 ⁶ L)	0.29	0.28
Operations (10 ⁶ L/yr)	0.084	0.052
Wastewater		
Construction (m ³)	6,900	6,600
Operations (m ³ /yr)	NA	NA
Excavated material (m ³)	1.65 × 10 ⁶	1.36 × 10 ⁶

^a NA = not applicable.

facility would create 40 direct jobs and produce \$2.0 million in direct income if disposal was in 30-gal containers, and 40 direct jobs and \$1.8 million if disposal was in 55-gal containers. For the 630,000 metric tons of UF₄, construction of the wasteform facility would create 110 direct jobs and \$4.3 million in direct income if 30-gal containers were used. If disposal was in 55-gal containers, 80 direct jobs and \$2.9 million in direct income would be created. Operation of the wasteform facility would create 40 direct jobs and produce \$2.0 million in direct income if disposal was in 30-gal containers, and 40 direct jobs and \$1.8 million if disposal was in 55-gal containers.

Construction of a shallow earthen structure for disposal of 500,000 metric tons of UF₄ in 30-gal containers would create 20 direct jobs and \$0.9 million in direct income. Disposal in 55-gal containers would create 20 direct jobs and \$0.8 million in direct income. Operation of the shallow

TABLE 6.14 Environmental Parameters for a Vault

Parameter	30-gal Drums	55-gal Drums
<i>Disposal of 500,000 Metric Tons of UF₄</i>		
Land area (ha)	25.4	31.6
Disturbed area (ha)	25.4	31.6
Water		
Construction (10 ⁶ L)	59.3	65.5
Operations (10 ⁶ L/yr)	0.076	0.084
Wastewater		
Construction (m ³)	14,000	15,000
Operations (m ³ /yr)	NA ^a	NA
Excavated material (m ³)	572,000	632,000
<i>Disposal of 630,000 Metric Tons of UF₄</i>		
Land area (ha)	31.6	37.9
Disturbed area (ha)	31.6	37.9
Water		
Construction (10 ⁶ L)	74.1	81.9
Operations (10 ⁶ L/yr)	0.076	0.084
Wastewater		
Construction (m ³)	16,000	17,000
Operations (m ³ /yr)	NA	NA
Excavated material (m ³)	714,000	790,000

^a NA = not applicable.

earthen structure would create 20 direct jobs and produce \$1.2 million in direct income if 30-gal containers were used, and 20 direct jobs and \$0.9 million if 55-gal containers were used. For 630,000 metric tons of UF₄, construction of the shallow earthen structure would create 20 direct jobs and \$0.7 million in direct income for both container sizes. Operation of the shallow earthen structure would create 20 direct jobs and produce \$1.3 million in direct income if 30-gal containers were used, and 20 direct jobs and \$1.0 million if 55-gal containers were used.

Construction of a vault for disposal of 500,000 metric tons of UF₄ in 30-gal containers would create 50 direct jobs and \$1.7 million in direct income. Disposal in 55-gal containers would create 50 direct jobs and \$1.9 million in direct income. Operation of the vault facility would create 50 direct jobs and produce \$2.7 million in direct income if 30-gal containers were used, and 40 direct

TABLE 6.15 Environmental Parameters for a Mined Cavity

Parameter	30-gal Drums	55-gal Drums
<i>Disposal of 500,000 Metric Tons of UF₄</i>		
Land area (ha)	236	168
Disturbed area (ha)	236	168
Water		
Construction (10 ⁶ L)	16.7	14.0
Operations (10 ⁶ L/yr)	3.09	2.33
Wastewater		
Construction (m ³)	58,000	52,000
Operations (m ³ /yr)	NA ^a	NA
Excavated material (m ³)	1.22 × 10 ⁶	990,000
<i>Disposal of 630,000 Metric Tons of UF₄</i>		
Land area (ha)	310	220
Disturbed area (ha)	310	220
Water		
Construction (10 ⁶ L)	19.4	16.1
Operations (10 ⁶ L/yr)	3.10	2.33
Wastewater		
Construction (m ³)	66,000	57,000
Operations (m ³ /yr)	NA	NA
Excavated material (m ³)	1.44 × 10 ⁶	1.16 × 10 ⁶

^a NA = not applicable.

jobs and \$2.1 million if 55-gal containers were used. For 630,000 metric tons of UF₄, construction of the vault facility would create 40 direct jobs and \$1.6 million in direct income if 30-gal containers were used, and 40 direct jobs and \$1.7 million in direct income if 55-gal containers were used. Operation of the vault facility would create 50 direct jobs and produce \$2.7 million in direct income if 30-gal containers were used, and 40 direct jobs and \$2.1 million if 55-gal containers were used.

Construction of a mined cavity for disposal of 500,000 metric tons of UF₄ in 30-gal containers would create 760 direct jobs and \$25.5 million in direct income. Disposal in 55-gal containers would create 680 direct jobs and \$22.8 million in direct income. Operation of the mined cavity would create 30 direct jobs and produce \$1.7 million in direct income if 30-gal containers were used, and 30 direct jobs and \$1.5 million if 55-gal containers were used. For the 630,000 metric tons of UF₄, construction of the mined cavity would create 860 direct jobs and \$28.9 million in direct

TABLE 6.16 Socioeconomic Impacts from UF₄ Disposal Options

UF ₄ Disposal Option and Socioeconomic Parameters	Disposal of 500,000 Metric Tons of UF ₄ per Phase and Drum Size				Disposal of 630,000 Metric Tons of UF ₄ per Phase and Drum Size			
	Construction ^a		Operations ^b		Construction ^a		Operations ^b	
	30-gal	55-gal	30-gal	55-gal	30-gal	55-gal	30-gal	55-gal
Wasteform facility								
Direct employment ^c (no. of persons)	110	80	40	40	110	80	40	40
Direct income (10 ⁶ year 2000 \$)	4.2	2.9	2.0	1.8	4.3	2.9	2.0	1.8
Shallow earthen structure								
Direct employment ^c (no. of persons)	20	20	20	20	20	20	20	20
Direct income (10 ⁶ year 2000 \$)	0.9	0.8	1.2	0.9	0.7	0.7	1.3	1.0
Vault								
Direct employment ^c (no. of persons)	50	50	50	40	40	40	50	40
Direct income (10 ⁶ year 2000 \$)	1.7	1.9	2.7	2.1	1.6	1.7	2.7	2.1
Mine								
Direct employment ^c (no. of persons)	760	680	30	30	860	740	30	30
Direct income (10 ⁶ year 2000 \$)	25.5	22.8	1.7	1.5	28.9	24.8	1.8	1.5

^a Impacts are from the peak year of construction: Year 3 for the wasteform facility, Year 5 or 6 for the mine. Impacts from constructing the shallow earthen structure or the vault would be identical in each year of the life of the facility, with construction continuing concurrently with waste placement.

^b Impacts are for the first year of operation.

^c For operations, direct employment includes those persons directly associated with operations, such as chemical operators, foremen, and technicians, plus their line supervision. Clerical and health physics support is also included. The values presented here represent the estimated number of workers for a “greenfield” site, where a new disposal facility would be constructed in support of depleted UF₄ disposal. The number of additional workers that would be required at an already existing disposal site would, in general, be less than those shown above.

income if 30-gal containers were used, and 740 direct jobs and \$24.8 million in direct income if 55-gal containers were used. Operation of the mined cavity would create 30 direct jobs and produce \$1.8 million in direct income if 30-gal containers were used, and 30 direct jobs and \$1.5 million if 55-gal containers were used.

The estimated number of direct jobs created for each option includes those persons directly associated with operations, such as chemical operators, foremen, and technicians, plus their line supervision. Clerical and health physics support is also included. The job estimates presented in this section represent the estimated number of workers for a “greenfield” site, where a new disposal facility would be constructed in support of depleted UF₄ disposal. The number of additional workers that would be required at an already existing disposal site would, in general, be less than those presented.

6.6 ECOLOGY

Moderate to large impacts on ecological resources could result from constructing a facility for disposal of UF₄. Impacts could include the death of individual organisms, habitat loss, or changes in biotic communities.

6.6.1 Disposal of 500,000 Metric Tons of UF₄

6.6.1.1 Shallow Earthen Structure

Preparing a site for the construction of a facility for the disposal of 500,000 metric tons of UF₄ in shallow earthen structures would require the elimination of approximately 46 acres (19 ha) of habitat for disposal in 55-gal drums and approximately 55 acres (22 ha) for disposal in 30-gal drums, including 2.7 to 3.3 acres (1.1 to 1.3 ha) for paved areas including that area needed for the wasteform facility. Existing vegetation would be destroyed during land clearing activities. The vegetative communities that would be eliminated by site preparation would depend on the actual location of the facility. A considerable period of time might be required to reestablish herbacious vegetation in a dry (less than 10 in./yr [25 cm/yr] precipitation) setting such as in the western United States. The loss of 46 to 55 acres (19 to 22 ha) of undeveloped land would constitute a moderate adverse impact on 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 on vegetation. Impacts from facility construction are shown in Table 6.17.

TABLE 6.17 Impacts on Ecological Resources from UF₄ Disposal Facility Construction

Resource	Impacts from Disposal Facility Construction per UF ₄ Disposal Option ^a		
	Shallow Earthen Structure	Vault	Mine
<i>Disposal of 500,000 Metric Tons of UF₄</i>			
Vegetation	Loss of 46 to 55 acres, moderate adverse impact	Loss of 67 to 82 acres, moderate adverse impact	Loss of 418 to 587 acres, large adverse impact
Wildlife	Loss of 46 to 55 acres, moderate adverse impact	Loss of 67 to 82 acres, moderate adverse impact	Loss of 418 to 587 acres, large adverse impact
Aquatic	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat
Wetlands	Potential loss, degradation	Potential loss, degradation	Potential loss, degradation
Protected species	Potential destruction, habitat loss	Potential destruction, habitat loss	Potential destruction, habitat loss
<i>Disposal of 630,000 Metric Tons of UF₄</i>			
Vegetation	Loss of 57 to 67 acres, moderate adverse impact	Loss of 82 to 97 acres, moderate to large adverse impact	Loss of 547 to 770 acres, large adverse impact
Wildlife	Loss of 57 to 67 acres, moderate adverse impact	Loss of 82 to 97 acres, moderate to large adverse impact	Loss of 547 to 770 acres, large adverse impact
Aquatic	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat
Wetlands	Potential loss, degradation	Potential loss, degradation	Potential loss, degradation
Protected species	Potential destruction, habitat loss	Potential destruction, habitat loss	Potential destruction, habitat loss

^a All acreages include the wasteform facility.

Wildlife would be disturbed by land clearing, noise, and human presence. Wildlife with restricted mobility, such as burrowing species or juveniles of nesting species, would be destroyed during land clearing activities. Mobile individuals would relocate to adjacent available areas with suitable habitat. Population densities and competition would increase in these areas, potentially reducing the chances of survival or reproductive capacity of displaced individuals. Some wildlife species would probably recolonize replanted areas near the disposal facility after the completion of construction. However, habitat use in the vicinity of the facility might be reduced for some species as a result of the construction of a perimeter fence. In summary, the loss of up to 55 acres (22 ha) of habitat as a result of the construction of a facility for disposal of 500,000 metric tons of UF₄ in shallow earthen structures would be considered a moderate adverse impact on wildlife.

Wetlands could be affected by filling or draining during construction. In addition, alteration of surface water runoff patterns, soil compaction, or groundwater flow could occur if the disposal facility was located adjacent to wetland or aquatic habitats. However, impacts would be minimized by maintaining a buffer area around wetlands and aquatic habitats during construction. Unavoidable impacts on wetlands would require a *Clean Water Act* Section 404 permit, which might stipulate mitigative measures. Additional permitting might be required by state agencies. Depending on the facility location, water withdrawal from surface water or groundwater, as well as wastewater discharge, could potentially alter water levels. These altered levels could, in turn, affect aquatic ecosystems, including wetlands, especially those located along the periphery of these surface water bodies.

Before construction of a disposal facility, a survey for state and federally listed threatened, endangered, or candidate species or species of special concern would be conducted so that impacts on these species could be avoided, if possible. If impacts were unavoidable, appropriate mitigation measures could be developed.

Facility accidents, as discussed in Section 6.3.2, could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on a number of factors, such as location of the accident, season, and meteorological conditions.

6.6.1.2 Vault

The construction and operation of a facility for the disposal of 500,000 metric tons of UF₄ in vaults would generally result in impacts similar to those associated with shallow earthen structures. However, the size of the facility and area of disturbance for vault disposal would be larger. Disposal in vaults would require the disturbance of approximately 67 to 82 acres (27 to 33 ha) of habitat, depending on the packaging option, including 9.5 to 11.6 acres (3.8 to 4.7 ha) for paved areas, including that area needed for the wasteform facility. This disposal option would elevate the soil surface as a result of the placement of excavated material and reduction in soil permeability. The decrease in soil moisture would make it difficult to reestablish vegetation and would delay the establishment of native plant communities. This disposal option would result in a moderate adverse impact on existing vegetation and wildlife. Reestablishment of native vegetation over such a large area would be especially difficult in a dry setting; a considerable period of time might be required.

6.6.1.3 Mine

The construction and operation of a facility for the disposal of 500,000 metric tons of UF₄ in a mine would generally result in impacts similar to those associated with vaults. However, the mine option would require the disturbance of approximately 418 to 587 acres (169 to 238 ha),

depending on the packaging option, including 27.9 to 30.5 acres (11 to 12 ha) for paved areas, including that area needed for the wasteform facility. This disposal option would elevate the soil surface and reduce soil permeability. The excavated material would primarily consist of rock removed from the drifts and ramps. The consequent decrease in surface soil moisture would make it difficult to reestablish vegetation and would delay the establishment of native plant communities. This disposal option would result in a large adverse impact on existing vegetation and wildlife. Reestablishment of native vegetation over such a large area would be especially difficult in a dry setting; a considerable period of time might be required.

6.6.2 Disposal of 630,000 Metric Tons of UF₄

The construction and operation of a facility for the disposal of 630,000 metric tons of UF₄ would generally result in the same types of impacts as those associated with the disposal of 500,000 metric tons of UF₄; however, the facility sizes would be larger. A shallow earthen structure disposal facility for 630,000 metric tons of UF₄ would eliminate approximately 57 to 67 acres (23 to 27 ha) of habitat, including the area for the wasteform facility. This habitat loss would result in a moderate adverse impact on vegetation and wildlife. Disposal in vaults would eliminate approximately 82 to 97 acres (33 to 39 ha) of habitat, including the area for the wasteform facility. This loss would result in a moderate to large adverse impact on vegetation and wildlife. A mine disposal facility would disturb approximately 547 to 770 acres (221 to 312 ha) of habitat, including the area for the wasteform facility. This habitat disturbance would result in a large adverse impact on vegetation and wildlife.

6.7 WASTE MANAGEMENT

Waste generated during the construction of the disposal facility would be typical of a large construction project. It would include construction debris such as concrete and scrap steel as well as sanitary waste from the labor force. No radioactive wastes would be generated during the construction of the wasteform facility or any of the three proposed disposal facilities because radioactive materials would not be used and the site would be uncontaminated. Construction wastes are listed in Table 6.18. Table 6.19 lists the various hazardous and nonhazardous wastes expected from the different disposal options. Estimates for the original inventory (500,000 metric tons) as well as the larger inventory (630,000 metric tons) of depleted UF₄ are included in the table. The waste generated during the construction of any of the disposal facilities would represent a negligible impact on DOE's waste management capabilities.

Because UF₄ forms a corrosive product in the presence of water, it is not suitable for grouting. Depleted UF₄ is a Class A waste under NRC's classification scheme. To be classified as a Class A waste, the waste must exhibit structural stability under expected disposal conditions. Such

TABLE 6.18 Estimated Construction Wastes Generated under UF₄ Disposal Options

UF ₄ Disposal Option and Waste Type	Disposal of 500,000 Metric Tons of UF ₄ per Drum Size				Disposal of 630,000 Metric Tons of UF ₄ per Drum Size			
	30-gal		55-gal		30-gal		55-gal	
	Annual ^a	Total	Annual ^a	Total	Annual ^a	Total	Annual ^a	Total
Wasteform facility								
Hazardous solids (m ³)	4.9	14.8	3.5	10.6	4.9	15.3	3.5	10.6
Hazardous liquids (m ³)	10.0	29.9	7.1	21.3	10.0	30.9	7.1	21.3
Nonhazardous solids								
Concrete (m ³)	36.7	110	30	90	36.7	110	30	90
Steel (metric tons)	0.6	1.7	0.5	1.4	0.6	1.8	0.5	1.4
Other (m ³)	297	890	230	690	297	920	230	690
Nonhazardous liquids								
Sanitary (m ³)	1,400	4,300	1,000	3,100	1,400	4,400	1,000	3,100
Other (m ³)	640	1,900	450	1,400	640	2,000	450	1,400
Shallow earthen structure								
Hazardous solids (m ³)	1.2	23	1.1	22	1.0	24	0.9	23
Hazardous liquids (m ³)	2.3	46	2.3	45	2.0	48	1.8	46
Nonhazardous solids								
Concrete (m ³)	0	0	0	0	0	0	0	0
Steel (metric tons)	0	0	0	0	0	0	0	0
Other (m ³)	0	0	0	0	0	0	0	0
Nonhazardous liquids								
Sanitary (m ³)	330	6,600	320	6,400	274	6,900	264	6,600
Other (m ³)	145	2,900	145	2,900	124	3,100	116	2,900
Vault								
Hazardous solids (m ³)	2.4	47	2.6	51	2.2	54	2.3	58
Hazardous liquids (m ³)	4.8	96	5.1	102	4.4	110	4.6	116
Nonhazardous solids								
Concrete (m ³)	133	2,660	147	2,940	133	3,330	147	3,680
Steel (metric tons)	1.1	22.0	1.2	24.5	1.1	28.0	1.2	30.5
Other (m ³)	1,050	21,000	1,200	24,000	1,100	27,000	1,200	29,000
Nonhazardous liquids								
Sanitary (m ³)	700	14,000	750	15,000	640	16,000	680	17,000
Other (m ³)	305	6,100	325	6,500	280	7,000	296	7,400

TABLE 6.18 (Cont.)

UF ₄ Disposal Option and Waste Type	Disposal of 500,000 Metric Tons of UF ₄ per Drum Size				Disposal of 630,000 Metric Tons of UF ₄ per Drum Size			
	30-gal		55-gal		30-gal		55-gal	
	Annual ^a	Total	Annual ^a	Total	Annual ^a	Total	Annual ^a	Total
Mine								
Hazardous solids (m ³)	26.7	200	23.9	179	30.2	227	26.0	195
Hazardous liquids (m ³)	54.2	406	48.4	363	61.2	459	52.6	395
Nonhazardous solids								
Concrete (m ³)	264	1,980	219	1,640	309	2,320	253	1,900
Steel (metric tons)	2.6	19.5	2.2	16.2	3.0	22.7	2.5	18.7
Other (m ³)	2,140	16,000	1,700	13,000	2,500	19,000	2,000	15,000
Nonhazardous liquids								
Sanitary	7,700	58,000	6,900	52,000	8,800	66,000	7,600	57,000
Other (m ³)	3,500	26,000	3,100	23,000	3,900	29,000	3,330	25,000

^a Construction waste generated in the disposal options for U₃O₈ and UO₂, as given in Appendix I of the PEIS (DOE 1999), should be compared to the annual generation rates for UF₄ disposal options.

Source: Folga and Kier (2001).

TABLE 6.19 Estimated Annual Radioactive and Nonhazardous Waste Streams from Wasteform Facility Operations

Waste Stream	Treatability Category	Annual Waste Stream (m ³) per UF ₄ Inventory			
		500,000 Metric Tons (20 yr)		630,000 Metric Tons (25 yr)	
		30-gal Drums	55-gal Drums	30-gal Drums	55-gal Drums
Facility waste (product) (LLW)	NA ^a	7,810	7,810	7,870	7,870
HEPA filters (LLW)	Noncombustible, compactable LLW	23.8	23.8	23.8	23.8
Damaged drums (LLW)	Surface-contaminated metal LLW	7.8	7.8	7.9	7.9
Other LLW	Combustible solid LLW	47.6	26.2	47.9	26.5
Inorganic solutions (LLMW)	Liquid LLMW	0.26	0.18	0.26	0.18
Nonhazardous (sanitary) wastes	NA	986	859	988	860
Nonhazardous (other) wastes	NA	78	68	78	68
Recyclable wastes	NA	31	27	31	27

^a NA = not applicable.

Source: Folga and Kier (2001).

stability can be achieved by placing the waste in a strong disposal container such as 30-gal or 55-gal drums. Under these conditions, the wasteform facility would consist of a product receiving, repackaging (where necessary), and shipping warehouse, which would include an administration building. The construction and operation period assumed for the shallow earthen structure and vault disposal facilities is 20 years for the original inventory (500,000 metric tons) and 25 years for the new inventory (630,000 metric tons); the construction period assumed is 7.5 years for the mined cavity disposal facility for both inventories, with an operational period of 20 years for the original inventory and 25 years for the new inventory. Table 6.20 lists the drum throughputs at the wasteform facility for each disposal option for both inventories. Table 6.19 lists the annual operational wastes from the wasteform facility for the original inventory (20-yr operation) and the new inventory (25-yr operation).

Estimates of the amount of LLW to be disposed of at DOE waste management disposal facilities depend critically upon the time frame under consideration and the types of waste. The Final Waste Management Programmatic Environmental Impact Statement (WM PEIS; DOE 1997) estimates that 1,060,000 m³ of LLW will be disposed of between 1995 and 2014. This estimate does not include any LLW from environmental restoration activities or facility stabilization activities. A more appropriate value is reported in *The 1996 Baseline Environmental Management Report* (BEMR) (DOE 1996), which estimates the total amount of LLW for treatment at waste management facilities to be 3,400,000 m³. This estimate is for 75 years and includes contributions from environmental restoration and facility stabilization programs.

The majority of environmental restoration wastes are expected to be generated between 2003 and 2033, approximately the correct time frame to compare with the depleted UF₄ wastes. Adjustments must be made to the BEMR estimate to convert treatment volumes into disposal

TABLE 6.20 Variations in Wasteform Facility Operations under UF₄ Disposal Options

Drum Size (gal)	UF ₄ Disposal Option	Annual Throughput Quantity (no. of drums/yr) per Inventory	
		500,000 Metric Tons UF ₄	630,000 Metric Tons UF ₄
30	Shallow earthen structure	68,650	69,160
55	Shallow earthen structure	37,450	37,720
30	Vault	68,650	69,160
55	Vault	37,450	37,720
30	Mine	183,100	230,500
55	Mine	99,900	125,700

volumes. Both reductions and expansions in volume would occur during waste treatment and grouting, depending on the relative amounts of the different types of waste. On the basis of the WM PEIS analysis (DOE 1997), the BEMR estimate of the disposal volume was adjusted to 4,250,000 m³. The total volumes of LLW from disposal of depleted uranium as UF₄ were compared with the total estimated volume of LLW for disposal from all DOE waste management activities (including environmental restoration waste). Disposal volumes were compared as total volume in cubic meters because disposal facilities would not typically have throughput limitations but would be limited in the total volume of waste that they could accept.

For the case of UF₄ with a waste volume of 7,810 m³/yr, the total disposal volume would be 156,000 m³ (7,810 m³ × 20-yr operation). This volume would add about 3.7% to the estimated total DOE LLW disposal volume of about 4,250,000 m³. Using a similar approach to the new inventory would add about 4.6% to the estimated total DOE LLW disposal volume. Secondary waste streams of LLW generated in the disposal of UF₄ (see Table 6.19) would have only a negligible impact on DOE LLW disposal capabilities. The amount of low-level mixed waste (LLMW) from depleted UF₄ disposal added to the total nationwide LLMW load would be negligible (less than 1%).

Overall, the disposal options would generate appreciable amounts of waste for disposal in DOE facilities. Within the context of the total amount of LLW undergoing disposal in DOE facilities, these wastes would have a small impact on DOE's total waste management disposal capabilities.

6.8 RESOURCE REQUIREMENTS

Resource requirements for the disposal options were estimated for construction and operations. The materials required for monitoring groundwater and disposal cell performance would be expected to be minor.

Materials and utilities required for construction and operation of the shallow earthen structure, vault, and mine options are listed in Tables 6.21 to 6.29. In general, the amounts of resources needed are directly related to the volume of waste to be disposed of. The total quantities of commonly used construction materials needed are not expected to be significant and would be comparable to those needed to build a multistory building. No specialty materials (e.g., Monel or Inconel) are projected to be needed for either construction or operations.

Significant quantities of electricity could be required during construction of the mine since most of the construction equipment is powered by electricity to avoid polluting the air in the underground work area. Similarly, the annual amount of electricity consumed during underground operations would be greater than the amount consumed in the other disposal facility options.

TABLE 6.21 Materials and Resources Required during Construction of Shallow Earthen Structure Disposal Facility^a

Item	30-gal Drums		55-gal Drums	
	Annual	Total ^a	Annual	Total ^a
500,000 Metric Tons of UF₄				
Water (10 ⁶ L)	0.014	0.28	0.014	0.27
Excavated material (m ³)	6.44E+04	1.29E+06	5.32E+04	1.06E+06
Clay (m ³)	437	8,740	392	7,840
Sand (m ³)	2,910	5.83E+04	2,340	4.69E+04
Gravel (metric tons)	122	2,440	99	1,970
Electricity (MWh)	220	4,410	185	3,700
Diesel fuel (L)	5.68E+04	1.14E+06	4.69E+04	9.38E+05
630,000 Metric Tons of UF₄				
Water (10 ⁶ L)	0.12	0.29	0.011	0.28
Excavated material (m ³)	6.58E+04	1.65E+06	5.44E+04	1.36E+06
Clay (m ³)	452	11,300	406	1.01E+04
Sand (m ³)	3,060	7.65E+04	2,480	6.20E+04
Gravel (metric tons)	128	3,200	104	2,600
Electricity (MWh)	222	5,560	186	4,640
Diesel fuel (L)	5.82E+04	1.45E+06	4.81E+04	1.20E+06

^a Totals are for 20 years of operations for 500,000 metric tons of UF₄ and 25 years of operations for 630,000 metric tons of UF₄.

TABLE 6.22 Resources Required during Operations of Shallow Earthen Structure Disposal Facility

Item	30-gal Drums		55-gal Drums	
	Annual	Total ^a	Annual	Total ^a
500,000 Metric Tons of UF₄				
Water (10 ⁶ L)	0.083	1.66	0.052	1.04
Electricity (MWh)	1,030	2.06E+04	762	1.52E+04
Diesel fuel (L)	1.48E+05	2.97E+06	8.21E+04	1.64E+06
630,000 Metric Tons of UF₄				
Water (10 ⁶ L)	0.084	2.09	0.052	1.31
Electricity (MWh)	1,030	2.58E+04	765	1.91E+04
Diesel fuel (L)	1.49E+05	3.73E+06	8.26E+04	2.07E+06

^a Totals are for 20 years of operations for 500,000 metric tons of UF₄ and 25 years of operations for 630,000 metric tons of UF₄.

TABLE 6.23 Materials and Resources Required during Construction of Vault Disposal Facility

Item	Per Vault	30-gal Drums		55-gal Drums	
		Annual	Total ^a	Annual	Total ^a
500,000 Metric Tons of UF₄					
Number of vaults	1	3.8	76	4.2	84
Concrete Redi-Mix (m ³)	1,750	6,650	133,000	7,350	147,000
Gravel (metric tons)	910	3,460	69,200	3,820	76,400
Liner (m ²)	2,220	8,440	168,700	9,320	186,500
Steel (metric tons)	58.5	220	4,400	250	4,900
Water (10 ⁶ L)	0.78	2.96	59.3	3.28	65.5
Excavated material (m ³)	7,520	28,600	572,000	31,600	632,000
Electricity (kWh)	12,500	47,500	950,000	52,500	1,050,000
Diesel fuel (L)	17,800	67,600	1,353,000	74,800	1,495,000
630,000 Metric Tons of UF₄					
Number of vaults	1	3.8	95	4.2	105
Concrete Redi-Mix (m ³)	1,750	6,650	1.66E+05	7,350	1.84E+05
Gravel (metric tons)	910	3,460	8.65E+04	3,820	9.56E+04
Liner (m ²)	2,220	8,440	2.11E+05	9,320	2.33E+05
Steel (metric tons)	58.5	58.5	5,600	250	6,100
Water (10 ⁶ L)	0.78	2.96	74.1	3.28	81.9
Excavated material (m ³)	7,520	2.86E+04	7.14E+05	3.16E+04	7.90E+05
Electricity (kWh)	1.25E+04	4.75E+04	1.19E+06	5.25E+04	1.31E+06
Diesel fuel (L)	1.78E+04	6.76E+04	1.69E+06	7.48E+04	1.87E+06

^a Totals are for 20 years of operations for 500,000 metric tons of UF₄ and 25 years of operations for 630,000 metric tons of UF₄.

TABLE 6.24 Resources Required during Operations of Vault Disposal Facility

Item	30-gal Drums			55-gal Drums		
	Per Vault	Annual	Total ^a	Per Vault	Annual	Total ^a
500,000 Metric Tons of UF₄						
Number of vaults	1	3.8	76	1	4.2	84
Water (10 ⁶ L)	0.02	0.076	1.52	0.02	0.084	1.68
Electricity (kWh)	328	1,250	2.49E+04	328	1,380	2.76E+04
Diesel fuel (L)	5.11E+04	1.94E+05	3.88E+06	5.11E+04	2.15E+05	4.29E+06
630,000 Metric Tons of UF₄						
Number of vaults	1	3.8	95	1	4.2	105
Water (10 ⁶ L)	0.02	0.076	1.9	0.02	0.084	2.1
Electricity (kWh)	328	1,250	3.12E+04	328	1,380	3.44E+04
Diesel fuel (L)	5.11E+04	1.94E+05	4.85E+06	5.11E+04	2.15E+05	5.37E+06

^a Totals are for 20 years of operations for 500,000 metric tons of UF₄ and 25 years of operations for 630,000 metric tons of UF₄.

TABLE 6.25 Total Materials and Resources Required during Construction of Mined Cavity Facility^a

Item	30-gal Drums	55-gal Drums
500,000 Metric Tons of UF₄		
Water (10 ⁶ L)	16.7	14.0
Concrete Redi-Mix (m ³)	9.90E+04	8.20E+04
Steel (metric tons)	3,890	3,230
Electricity (GWh)	5,760	4,810
Diesel fuel (L)	7.16E+05	5.83E+05
Excavated material (m ³)	1.22E+06	9.90E+05
630,000 Metric Tons of UF₄		
Water (10 ⁶ L)	19.4	16.1
Concrete Redi-Mix (m ³)	1.16E+05	9.50E+04
Steel (metric tons)	4,540	3,740
Electricity (GWh)	6,670	5,540
Diesel fuel (L)	8.46E+05	6.84E+05
Excavated material (m ³)	1.44E+06	1.16E+06

^a Totals are for 20 years of operations for 500,000 metric tons of UF₄ and 25 years of operations for 630,000 metric tons of UF₄.

TABLE 6.26 Resources Required during Operations of Mined Cavity Facility

Item	30-gal Drums		55-gal Drums	
	Annual	Total ^a	Annual	Total ^a
500,000 Metric Tons of UF₄				
Water (10 ⁶ L)	3.09	61.8	2.33	46.5
Electricity (MWh)	8,310	1.66E+05	6,140	1.23E+05
Diesel fuel (L)	9,300	1.86E+05	6,230	1.25E+05
630,000 Metric Tons of UF₄				
Water (10 ⁶ L)	3.10	77.5	2.33	58.3
Electricity (MWh)	8,340	2.09E+05	6,160	1,54E+05
Diesel fuel (L)	9,350	2.34E+05	6,260	1.57E+05

^a Totals are for 20 years of operations for 500,000 metric tons of UF₄ and 25 years of operations for 630,000 metric tons of UF₄.

TABLE 6.27 Total Materials and Resources Required during Construction of Wasteform Facility

Item	30-gal Drums	55-gal Drums
<i>500,000 Metric Tons of UF₄</i>		
Water (10 ⁶ L)	3.3	2.7
Concrete Redi-Mix (m ³)	5,591	4,286
Steel (metric tons)	349	271
Excavated material (m ³)	9,550	7,550
Electricity (MWh)	480	410
Masonry brick (m ²)	573	573
Diesel fuel (L)	90,000	70,000
<i>630,000 Metric Tons of UF₄</i>		
Water (10 ⁶ L)	3.4	2.7
Concrete Redi-Mix (m ³)	5,724	4,286
Steel (metric tons)	357	271
Excavated material (m ³)	9,750	7,550
Electricity (MWh)	487	410
Masonry brick (m ²)	573	573
Diesel fuel (L)	92,000	70,000

TABLE 6.28 Total Concrete Required for Wasteform Facility

Structure	Concrete Required (m ³)			
	Floor	Walls	Roof	Total
<i>500,000 Metric Tons of UF₄</i>				
Warehouse ^a				
30-gal drums	2,482	759	2,068	5,308
55-gal drums	1,871	572	1,559	4,003
Administration bldg.	88	94	101	283
<i>630,000 Metric Tons of UF₄</i>				
Warehouse ^a				
30-gal drums	2,544	778	2,120	5,441
55-gal drums	1,871	572	1,559	4,003
Administration bldg.	88	94	101	283

^a Warehouse = product receiving and shipping warehouse.

TABLE 6.29 Resources Required during Operations of Wasteform Facility

Item	30-gal Drums		55-gal Drums	
	Annual	Total ^a	Annual	Total ^a
500,000 Metric Tons of UF₄				
Water (10 ⁶ L)	0.62	12	0.52	10
Natural gas, therms (1E+05 Btu)	141	2,830	112	2,240
Electricity (MWh)	671	13,400	579	11,600
Diesel fuel (L)	556	11,100	502	10,000
630,000 Metric Tons of UF₄				
Water (10 ⁶ L)	0.63	16	0.52	13
Natural gas, therms (1E+05 Btu)	144	3,610	112	2,800
Electricity (MWh)	680	17,000	579	14,500
Diesel fuel (L)	561	14,000	502	12,600

^a Totals are for 20 years of operations for 500,000 metric tons of UF₄ and 25 years of operations for 630,000 metric tons of UF₄.

6.9 LAND USE

Land area requirements for each disposal option were presented in Tables 5.2 through 5.4. These data did not include acreage required for constructing any of the disposal options because the development of land would occur incrementally, and the space needed for excavation material storage areas, equipment staging areas, and construction material laydown areas would be available on adjacent, undeveloped parcels. Consequently, areal needs for construction would not be greater than those for operations.

If the facility site selected was at or near a location that is already used for a similar purpose, land-use impacts could be reduced, because immediate access to infrastructure and utility support would require only minor disturbances to existing land use.

All disposal options would include a central wasteform facility where drums would be received from the conversion facility and prepared for disposal. Impacts on land use from the wasteform facility would be very small and limited to clearing of required land and possibly minor and temporary disruptions to contiguous land parcels. No off-site impacts would be expected.

Land-use impacts resulting from the shallow earthen structure disposal option would be negligible to moderate and limited to clearing of required land and possibly a slight increase in the amount of off-site vehicular traffic associated with construction activities. The large volume of

excavated material that would remain on site could, over time, result in topographical modifications of the site. Impacts from off-site disposal would be determined during the site-specific tier of National Environmental Policy Act (NEPA) documentation. Other than minor, temporary impacts associated with construction traffic, no other off-site impacts would be expected.

Because the vault facility would be constructed incrementally (10 vault blocks per year), the amount of land disturbed during a given year would be limited. Impacts from off-site disposal would be determined during the site-specific tier of NEPA documentation.

Of all the disposal options, a mine would have the greatest potential for land-use impacts because it would require the largest amount of land (see Tables 5.3 and 5.4). The construction associated with this option could disturb adjacent parcels of land. The large volume of excavated material would be disposed of on site, probably resulting in topographical modifications of the site. The peak construction labor force could cause off-site land-use impacts, particularly if a remote site was chosen. Impacts could involve existing commercial land and traffic on local access roads and intersections.

6.10 OTHER IMPACTS CONSIDERED BUT NOT ANALYZED IN DETAIL

Other impacts that could occur if the disposal options considered in this report were implemented include impacts on cultural resources, environmental justice, the visual environment (e.g., aesthetics), recreational resources, and noise levels. Impacts could also result from the decontamination and decommissioning of the disposal facilities. These impacts were considered but could not be analyzed in detail without knowledge of the specific sites. These impacts could be more appropriately addressed in later NEPA documentation when specific sites are being considered.

7 IMPACTS OF OPTIONS — POST-CLOSURE PHASE

This section provides a summary of the potential environmental impacts associated with the post-closure phase of the disposal options. The post-closure phase covers a future time, well beyond the time any engineered disposal facility would be expected to function as designed. Post-closure impacts were evaluated because no matter how well-designed a disposal facility would be, it would still probably release uranium compounds to the environment. This condition is referred to as “failure.”

Disposal facility failure would generally occur hundreds to thousands of years in the future (assuming there was no sustained effort to maintain the facility). This failure would be caused by natural degradation of the disposal structures over time, primarily from physical processes such as the intrusion of water. Following failure, the release of uranium from the facility would occur very slowly as water moved through the disposed material. This water would carry dissolved uranium through the soil under the facility, eventually contaminating the groundwater. This process could continue for thousands to millions of years because of the large amount of uranium in the disposal facility and low solubility of that uranium.

In general, shallow earthen structures would be expected to contain waste material for at least several hundred years before failure. Vaults and a mine would be expected to last even longer before failure, from many hundreds of years to thousands of years. However, the exact time that a disposal facility would be expected to fail is extremely difficult to predict and would depend on the detailed facility design and site-specific conditions. Because of this uncertainty, failure was assumed to occur at the end of a period of institutional control, 100 years after closure. The post-closure impacts were evaluated at 1,000 years after failure for all three disposal facility options.

Potential post-closure impacts were evaluated on three areas: (1) groundwater, (2) human health and safety, and (3) ecological resources. Impacts on other areas would be expected to be negligible. The following general assumptions apply to the assessment of post-closure impacts:

- C All disposal facilities would fail at some time in the future. Failure is defined as the release of uranium material from the disposal facility to the surrounding soil. For consistency, failure was assumed to occur at the end of institutional control, 100 years after closure.
- C The post-closure phase primarily considers potential impacts from the contamination of groundwater and surface water. Potential impacts from the contamination of air and soil due to erosion of the disposal facility surface are also discussed.

- C The impacts evaluated were those that would occur 1,000 years after the facility failed and started to release uranium.
- C For analysis of groundwater impacts, assumptions were varied to assess a broad range of possibilities with respect to movement of the uranium through the soil to the groundwater aquifer.

The estimated impacts associated with the post-closure phase are subject to a great deal of uncertainty because the assessment considers an extremely long period of time and depends on predicting the behavior of the waste material as it interacts with soil and water in a complex and changing environment. Consequently, the estimated impacts are very dependent on the assessment assumptions. Key assumptions include such factors as soil characteristics, water infiltration rates, depth to the underlying groundwater table, chemistry of different uranium compounds, and the locations of future human receptors. These factors can vary widely depending on site-specific conditions. Because of these uncertainties, the assumptions were generally selected in a manner intended to produce conservative estimates of impact, that is, the assumptions tend to overestimate the expected impact. Changes in key disposal assumptions could yield significantly different estimates of impact.

7.1 HUMAN HEALTH — NORMAL OPERATIONS

7.1.1 Radiological Impacts

Radiation doses and cancer risks for the post-closure phase were assessed for a hypothetical individual who would live at or near the disposal site after the institutional control period of the site ended. This individual was assumed to drill a well at the edge of the disposal site and use the well water for drinking, household purposes, irrigating plant foods and fodder, and watering livestock. Because of leaching of uranium from the disposal area to the groundwater table, the hypothetical resident could be exposed to radiation through use of contaminated well water. Detailed discussions of the methodologies used in radiological impact analyses are provided in Cheng et al. (1997). Additional information on the methodology and assumptions used in the groundwater analyses is provided in Section 7.2.

The estimated groundwater concentrations involve large degrees of uncertainty because of the preliminary nature of facility design and the various soil properties that depend on the location of the facility. The radiological impacts estimated by using the groundwater concentrations are subject to a large degree of uncertainty as well. The groundwater contamination would persist for millions of years once it occurred because of the large inventory of UF_4 in the disposal area. Because of the long decay half-lives of uranium isotopes and the continuous generation of decay products,

the maximum radiation dose, which could be greater than 1 rem/yr from using contaminated groundwater, would not be observed until sometime after 10,000 years, a time frame well beyond that considered in this analysis. Table 7.1 lists the calculated radiation doses and cancer risks for the maximally exposed individual (MEI) 1,000 years after the failure of engineering barriers and waste containers. Because of the assumption that the disposal facility would be at a dry location, potential radiation exposure would be minimal at that time, less than 3×10^{-6} mrem/yr .

In addition to the possible exposures resulting from use of contaminated groundwater, radiological impacts could be caused by external radiation and inhalation of contaminated dust particles if all the cover materials above the disposal site were removed and if containers of UF₄ disintegrated. This scenario could be caused by natural forces of erosion over long periods of time or by human intervention (i.e., digging) to bring the waste to the surface. The associated external radiation dose could be as high as 10 rem/yr for an individual living on the disposal site. However, the exposure would not occur until several thousand years after closure of the shallow earthen structure or vault disposal facility, and exposure would be quite unlikely if mines were used for disposal because a mine would be located several hundred feet below the ground surface. Detailed analyses for this exposure scenario were not conducted because the time frame would be beyond that considered in this analysis. If any exposure would occur, the radiation dose could be eliminated by adding new cover materials to the top of the waste area.

7.1.1.1 Disposal of 500,000 Metric Tons of UF₄

Radiological impacts are listed in Table 7.1 for a scenario in which an individual uses contaminated groundwater. In a dry setting, because of the low water infiltration rate and the long distance from the bottom of the disposal area to the groundwater table, the amount of radionuclides that would reach the groundwater table within 1,000 years would be very small.

7.1.1.2 Disposal of 630,000 Metric Tons of UF₄

Potential radiation exposure from using contaminated groundwater would be slightly greater for disposal of 630,000 metric tons of UF₄ than for disposal of 500,000 metric tons of UF₄, because of the larger disposal area used. However, in a dry location, as was assumed for the analysis, the amount of radionuclides that would reach the groundwater table 1,000 years after failure of the disposal facility would still be minimal. The estimated maximum radiation dose would be less than 3×10^{-6} mrem/yr.

TABLE 7.1 Estimated Human Health Impacts to the MEI under UF₄ Disposal Options during the Post-Closure Phase

Option/Inventory ^a	Radiological Impacts at 1,000 Years ^{b,c}		Chemical Impacts at 1,000 Years ^{b,c}
	MEI Dose (mrem/yr)	MEI risk (LCF/yr)	MEI Hazard Index ^d
<i>Disposal of 500,000 Metric Tons of UF₄</i>			
Shallow earthen structure			
30-gal drums	$< 2.2 \times 10^{-8}$	$< 1 \times 10^{-14}$	3×10^{-9}
55-gal drums	$< 2.0 \times 10^{-8}$	$< 1 \times 10^{-14}$	2×10^{-9}
Vault			
30-gal drums	$< 2.9 \times 10^{-8}$	$< 1 \times 10^{-14}$	4×10^{-9}
55-gal drums	$< 3.2 \times 10^{-8}$	$< 2 \times 10^{-14}$	2×10^{-9}
Mine			
30-gal drums	$< 2.3 \times 10^{-6}$	$< 1 \times 10^{-12}$	3×10^{-7}
55-gal drums	$< 2.0 \times 10^{-6}$	$< 1 \times 10^{-12}$	2×10^{-7}
<i>Disposal of 630,000 Metric Tons of UF₄</i>			
Shallow earthen structure			
30-gal drums	$< 2.4 \times 10^{-8}$	$< 1 \times 10^{-14}$	3×10^{-9}
55-gal drums	$< 2.2 \times 10^{-8}$	$< 1 \times 10^{-14}$	3×10^{-9}
Vault			
30-gal drums	$< 2.9 \times 10^{-8}$	$< 1 \times 10^{-14}$	4×10^{-9}
55-gal drums	$< 3.2 \times 10^{-8}$	$< 2 \times 10^{-14}$	4×10^{-9}
Mine			
30-gal drums	$< 2.5 \times 10^{-6}$	$< 1 \times 10^{-12}$	3×10^{-7}
55-gal drums	$< 2.1 \times 10^{-6}$	$< 1 \times 10^{-12}$	4×10^{-7}

^a Two inventories were considered for each option: 500,000 metric tons of UF₄ and 630,000 metric tons of UF₄. The first inventory results from converting 560,000 metric tons of UF₆ that DOE facilities generated in the past. The second inventory results from converting 705,000 metric tons of UF₆ that both DOE generated and USEC generated.

^b Impacts are reported as the maximum values, which result from considering different solubilities of uranium compounds that may be formed and different transport speeds of radionuclides in the unsaturated and saturated zones. Retardation factors of 5 and 50 were used to represent relatively mobile and immobile transport situations, respectively. Solubilities considered a range from 2.4×10^{-3} to 24 g/L.

^c The maximally exposed individual (MEI) was assumed to live at the edge of the disposal site and use contaminated groundwater for drinking, irrigating plant food and fodder, and feeding livestock. The exposure pathways considered were ingestion of drinking water, plant foods, meat, and milk; and, for radiological exposures, inhalation of radon emanating from household water.

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

7.1.2 Chemical Impacts

Chemical impacts during the post-closure phase were assessed for a hypothetical individual who lives at the border of the disposal site after the institutional control period is over. As they were for the radiological assessment, potential chemical impacts on human health were evaluated for a scenario involving a hypothetical individual who drills a well at the edge of the disposal site and uses the well water for drinking, irrigating plant foods and fodder, and watering livestock. Leaching of uranium from the disposal area to the groundwater table could potentially result in the hypothetical resident being exposed to uranium from ingestion of drinking water, plant foods, meat, and milk. Risks are estimated on the basis of calculated hazard indices. Information on the exposure assumptions, health effects assumptions, reference doses used for uranium compounds, and calculational methods used in the chemical impact analysis are provided in Appendix C of the PEIS (DOE 1999) and Cheng et al. (1997).

Potential health impacts on the general public MEI from exposures to hazardous chemicals due to use of groundwater are listed in Table 7.1. The hazard indices for chemical impacts are essentially zero because of the assumption that the disposal facility would be located in a dry environmental setting.

7.2 GROUNDWATER

For the three disposal options during the post-closure phase, there would be no impacts on effective recharge, depth to groundwater, or the direction of groundwater flow. Water quality would be the only groundwater feature that might be affected. With time, the disposal facilities would fail and allow water to infiltrate the storage area. This water could corrode the drums and permit leaching of their contents. Because UF_4 is soluble and undergoes hydrolysis, a wide variety of uranium compounds could form. One of the uranium compounds is schoepite ($UO_3 \cdot 2H_2O$). Other more complex compounds would also be possible, depending on site-specific conditions.

For each mole of schoepite formed, four moles of HF would be released. HF is a weak acid (i.e., it does not readily dissociate into hydrogen and fluoride ions); however, it is very corrosive and readily forms a gas (volatilizes). Specific analyses of the impact of HF on groundwater were not performed for the following reasons: HF has low vapor pressure and boils at room temperatures, thereby reducing the aqueous phase concentration; HF is very corrosive and reacts readily with its surroundings, particularly the metal drums containing the disposed UF_4 ; as an ion, fluoride has a moderately high coefficient for sorption while in transport (Tomasko 2001); and the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for fluoride (4 mg/L) is much higher than the proposed MCL for uranium (20 : g/L) (EPA 1996).

With additional time (several hundred to thousands of years), the facility would fail completely, and dissolved uranium complexes would infiltrate the soil beneath the structure and interact with soil water present in the unsaturated zone. Transport of the dissolved uranium would be influenced by advection, dispersion, adsorption, and decay (Tomasko 1997).

At the water table, the dissolved uranium compounds would mix with initially clean water in the uppermost groundwater aquifer and be diluted. After mixing and dilution, the contaminants would be transported in a direction consistent with natural flow. Advection, dispersion, adsorption, and decay would again influence the transport process (Tomasko 1997).

Uranium concentrations and activities at the water table for a dry environmental setting are summarized in Tables 7.2 and 7.3 for 1,000 years after failure for a shallow earthen structure, vault, and mine. Values are reported for initial total inventories of 500,000 and 630,000 metric tons of UF_4 , disposal in 30-gal and 55-gal drums, fairly mobile (retardation equal to 5) and fairly immobile transport (retardation equal to 50), and low-solubility and high-solubility uranium compounds. Details on these calculations can be found in Tomasko (2001).

The highest uranium groundwater concentrations, 8.6×10^{-6} pCi/L (5.5×10^{-5} : g/L), would result from a failed mine in which 500,000 metric tons of UF_4 was disposed of in 30-gal drums. The lowest concentrations, 1.2×10^{-9} pCi/L (5.2×10^{-9} : g/L), would result from disposing of 500,000 metric tons of UF_4 in a shallow earthen structure in 55-gal drums. All of the predicted concentrations would be much less than the proposed MCL of 20 : g/L (EPA 1996) used for comparison. Impacts on groundwater quality could be further reduced by decreasing the size of the facility in a direction parallel to the direction of groundwater flow, thereby increasing dilution.

Varying the distance to the receptor from 0 to 1,000 ft (300 m) would have no effect on concentrations because of the short travel distance and the travel velocity of the groundwater.

7.3 ECOLOGY

Predicted concentrations of contaminants in groundwater were compared to benchmark values of toxic and radiological effects to assess impacts to biota. A discussion of the assessment methodology is presented in Appendix C of the PEIS (DOE 1999).

TABLE 7.2 Concentrations 1,000 Years after Dilution at the Water Table for Disposal of 500,000 Metric Tons of UF₄

Solubility (g/L)	Facility	30-gal Drums			55-gal Drums		
		C/C ₀	Concentration (g/L)	Activity Concentration (pCi/L)	C/C ₀	Concentration (g/L)	Activity Concentration (pCi/L)
2.4×10^{-3}	Shallow earthen structure	2.4×10^{-12} 6.9×10^{-24}	5.8×10^{-15} 1.7×10^{-26}	1.4×10^{-9} 4.1×10^{-21}	2.2×10^{-12} 6.3×10^{-24}	5.2×10^{-15} 1.6×10^{-26}	1.2×10^{-9} 3.7×10^{-21}
	Vault	2.6×10^{-12} 7.6×10^{-24}	6.3×10^{-15} 1.9×10^{-26}	1.5×10^{-9} 4.5×10^{-21}	2.9×10^{-12} 8.5×10^{-24}	7.0×10^{-15} 2.1×10^{-26}	1.7×10^{-9} 5.0×10^{-21}
	Mine	1.5×10^{-11} 6.6×10^{-12}	3.7×10^{-14} 1.6×10^{-14}	9.0×10^{-9} 3.8×10^{-9}	1.3×10^{-11} 5.8×10^{-12}	3.2×10^{-14} 1.4×10^{-14}	7.8×10^{-9} 3.3×10^{-9}
24	Shallow earthen structure	2.2×10^{-14} 3.8×10^{-24}	5.1×10^{-13} 9.2×10^{-23}	8.1×10^{-8} 1.5×10^{-17}	2.0×10^{-14} 3.5×10^{-24}	4.7×10^{-13} 8.5×10^{-23}	7.5×10^{-8} 1.4×10^{-17}
	Vault	2.8×10^{-14} 3.8×10^{-24}	6.6×10^{-13} 9.0×10^{-23}	1.1×10^{-7} 1.5×10^{-17}	3.1×10^{-14} 4.2×10^{-24}	7.4×10^{-13} 1.0×10^{-22}	1.2×10^{-7} 1.6×10^{-17}
	Mine	2.2×10^{-12} 2.2×10^{-14}	5.5×10^{-11} 5.1×10^{-13}	8.6×10^{-6} 8.2×10^{-8}	1.9×10^{-12} 1.9×10^{-14}	4.6×10^{-11} 4.5×10^{-13}	7.4×10^{-6} 7.2×10^{-8}

TABLE 7.3 Concentrations 1,000 Years after Dilution at the Water Table for Disposal of 630,000 Metric Tons of UF₄

Solubility (g/L)	Facility	30-gal Drums			55-gal Drums		
		C/C ₀	Concentration (g/L)	Activity Concentration (pCi/L)	C/C ₀	Concentration (g/L)	Activity Concentration (pCi/L)
2.4×10^{-3}	Shallow earthen structure	2.6×10^{-12} 7.7×10^{-24}	6.3×10^{-15} 1.9×10^{-26}	1.5×10^{-9} 4.5×10^{-21}	2.4×10^{-12} 7.1×10^{-24}	5.8×10^{-15} 1.7×10^{-26}	1.4×10^{-9} 4.2×10^{-21}
	Vault	2.9×10^{-12} 7.7×10^{-24}	7.0×10^{-15} 5.0×10^{-21}	1.7×10^{-9} 1.2×10^{-15}	3.2×10^{-12} 9.3×10^{-24}	7.7×10^{-15} 2.3×10^{-26}	1.8×10^{-9} 5.5×10^{-21}
	Mine	1.7×10^{-11} 7.4×10^{-12}	4.1×10^{-14} 1.8×10^{-14}	1.0×10^{-8} 4.2×10^{-9}	1.5×10^{-11} 6.5×10^{-12}	3.6×10^{-14} 1.5×10^{-14}	8.8×10^{-9} 3.7×10^{-9}
24	Shallow earthen structure	2.3×10^{-14} 4.8×10^{-24}	5.5×10^{-13} 1.1×10^{-22}	8.9×10^{-8} 1.8×10^{-17}	2.1×10^{-14} 4.4×10^{-24}	5.0×10^{-13} 1.1×10^{-22}	8.0×10^{-8} 1.8×10^{-17}
	Vault	2.8×10^{-14} 4.8×10^{-24}	6.6×10^{-13} 1.2×10^{-22}	1.1×10^{-7} 1.8×10^{-17}	3.1×10^{-14} 5.2×10^{-24}	7.4×10^{-13} 1.3×10^{-22}	1.2×10^{-7} 2.1×10^{-17}
	Mine	2.4×10^{-12} 3.0×10^{-14}	5.7×10^{-11} 7.0×10^{-13}	9.2×10^{-6} 1.1×10^{-7}	2.1×10^{-12} 2.6×10^{-14}	5.0×10^{-11} 6.2×10^{-13}	8.0×10^{-6} 9.9×10^{-8}

7.3.1 Disposal of 500,000 Metric Tons of UF₄

The disposal facilities considered would be expected to adequately prevent the release of their contents for considerable periods of time. Impacts on ecological resources due to the presence of the facility would not be expected to occur before facility failure. Failure of facility integrity would eventually result in contamination of groundwater. Groundwater could discharge to the surface (such as in wetland areas), thus exposing biota to contaminants. Groundwater concentrations of uranium compounds (e.g., UO₃·H₂O) were calculated for 1,000 years after facility failure (Section 7.2). Concentrations would be very low throughout the time period analyzed for a disposal facility located in a dry environmental setting (typical of the western United States, with less than 10 in./yr [25 cm/yr] precipitation). Ecological impacts are summarized in Table 7.4.

Failure of a shallow earthen structure disposal facility would result in groundwater concentrations of uranium compounds near the facility ranging from 1.6×10^{-26} to 5.1×10^{-13} g/L. Soluble uranium compounds can produce toxic effects in aquatic biota at concentrations as low as 1.5×10^{-4} g/L. Toxic effects on an organism continuously exposed to the undiluted groundwater would be expected to be negligible. Uranium activity would range from 3.7×10^{-21} to 8.1×10^{-8} pCi/L. Resulting dose rates to maximally exposed organisms would be much less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d for aquatic organisms specified in DOE Order 5400.5.

Failure of a facility for disposal in vaults would result in groundwater concentrations of uranium compounds ranging from 1.9×10^{-26} to 7.4×10^{-13} g/L. Toxic effects on an organism continuously exposed to this undiluted groundwater would be expected to be negligible. Uranium activity would range from 4.5×10^{-21} to 1.2×10^{-7} pCi/L. Resulting dose rates to maximally exposed organisms would be much less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

Failure of a mine disposal facility would result in groundwater concentrations ranging from 1.4×10^{-14} to 5.5×10^{-11} g/L. Adverse impacts to aquatic biota would be expected to be negligible. Uranium activity would range from 3.3×10^{-9} to 8.6×10^{-6} pCi/L. Resulting dose rates to maximally exposed organisms would be much less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

7.3.2 Disposal of 630,000 Metric Tons of UF₄

Groundwater uranium concentrations resulting from the failure of a facility for disposal of 630,000 metric tons of UF₄ would also be very low at 1,000 years for a facility in a dry environmental setting.

TABLE 7.4 Potential Radiological and Chemical Impacts on Aquatic Biota from Failure of a Disposal Facility

Disposal Option/ Contaminant in Groundwater	Maximum Exposure	Effect
<i>Disposal of 500,000 Metric Tons of UF₄</i>		
Shallow earthen structure		
Uranium activity	3.7×10^{-21} to 8.1×10^{-8} pCi/L	Toxic effect: negligible
Uranium concentration	1.6×10^{-26} to 5.1×10^{-13} g/L	Dose to MEI: negligible
Vault		
Uranium activity	4.5×10^{-21} to 1.2×10^{-7} pCi/L	Toxic effect: negligible
Uranium concentration	1.9×10^{-26} to 7.4×10^{-13} g/L	Dose to MEI: negligible
Mine		
Uranium activity	3.3×10^{-9} to 8.6×10^{-6} pCi/L	Toxic effect: negligible
Uranium concentration	1.4×10^{-14} to 5.5×10^{-11} g/L	Dose to MEI: negligible
<i>Disposal of 630,000 Metric Tons of UF₄</i>		
Shallow earthen structure		
Uranium activity	4.2×10^{-21} to 8.9×10^{-8} pCi/L	Toxic effect: negligible
Uranium concentration	1.7×10^{-26} to 5.5×10^{-13} g/L	Dose to MEI: negligible
Vault		
Uranium activity	5.5×10^{-21} to 1.2×10^{-7} pCi/L	Toxic effect: negligible
Uranium concentration	2.3×10^{-26} to 7.4×10^{-13} g/L	Dose to MEI: negligible
Mine		
Uranium activity	3.7×10^{-9} to 9.2×10^{-6} pCi/L	Toxic effect: negligible
Uranium concentration	1.5×10^{-14} to 5.7×10^{-11} g/L	Dose to MEI: negligible

Failure of a shallow earthen structure facility would result in groundwater concentrations of uranium compounds near the facility ranging from 1.7×10^{-26} to 5.5×10^{-13} g/L. Soluble uranium compounds can produce toxic effects in aquatic biota at concentrations as low as 1.5×10^{-4} g/L. Toxic effects on an organism continuously exposed to the undiluted groundwater would be expected to be negligible. Uranium activity would range from 4.2×10^{-21} to 8.9×10^{-8} pCi/L. Resulting dose rates to maximally exposed organisms would be much less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

Failure of a facility for disposal in vaults would result in groundwater concentrations of uranium compounds ranging from 2.3×10^{-26} to 7.4×10^{-13} g/L. Toxic effects on an organism continuously exposed to this undiluted groundwater would be expected to be negligible. Uranium

activity would range from 5.5×10^{-21} to 1.2×10^{-7} pCi/L. Resulting dose rates to maximally exposed organisms would be much less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

Failure of a mined cavity disposal facility would result in groundwater uranium concentrations ranging from 1.5×10^{-14} to 5.7×10^{-11} g/L. Adverse impacts to aquatic biota would be expected to be negligible. Uranium activity would range from 3.7×10^{-9} to 9.2×10^{-6} pCi/L. Resulting dose rates to maximally exposed organisms would be considerably lower than the dose limit of 1 rad/d.

8 TRANSPORTATION IMPACTS

Disposal of UF₄ would require it to be shipped from a conversion plant to the disposal facility. The UF₄ would be packaged in 30-gal or 55-gal drums and shipped by either truck or train, in accordance with DOE and Department of Transportation regulatory requirements. The numbers of shipments required for both the original and new inventories are summarized in Table 8.1.

The assessment of potential transportation impacts considered both truck and rail shipment options and evaluated impacts from both normal (incident-free) transportation operations and accidents. Potential health impacts from both radiological and chemical exposures to UF₄ were estimated. Because the locations of conversion and disposal facilities are not known, transportation impacts were estimated for representative routes with shipment distances of 250, 1,000, and 5,000 km to provide a reasonable range. Additional transportation assumptions and discussion are provided in Appendix J of the PEIS (DOE 1999).

During normal transportation operations, UF₄ would be contained in the transport packages. Potential health impacts would be possible from exposure to low-level external radiation in the vicinity of shipments. In addition, exposure to vehicle engine exhaust emissions could cause adverse effects.

Accidents could occur during the transportation of UF₄. These accidents could potentially affect the health of workers (i.e., crew members) and members of the general public. Potential impacts were estimated for two types of accidents: (1) typical traffic accidents that could cause deaths from physical trauma, unrelated to the cargo being shipped, and (2) accidents that could involve the release of UF₄ from a shipment, potentially resulting in radiological and chemical exposures.

The estimated risks during routine transportation operations are presented in Table 8.1. Accident risk estimates, which include the probability of accidents occurring, are summarized in Table 8.2. The potential consequences from severe accidents are summarized in Table 8.3 for populations and Table 8.4 for MEIs. Risks to an MEI during routine transportation conditions are summarized in Table 8.5.

In general, the total risks associated with depleted UF₄ transport would be dominated by vehicle-related risks, which would be about 5 times larger than the radiological and chemical risks combined. Also, risks from transport by rail appear to be slightly less than the truck risks because rail transport is associated with higher shipment capacities and therefore fewer shipments. There are no significant differences between the 30-gal and 55-gal drum options because the total amount of material per shipment would remain approximately the same.

TABLE 8.1 Total Risks from Routine Shipment of UF₄

Drum Size (gal)	Mode	Total Shipments ^a	Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
			Radiological LCF ^b	Chemical Effects ^c	Vehicular LCF	Radiological LCF ^b	Chemical Effects ^c	Vehicular LCF	Radiological LCF ^b	Chemical Effects ^c	Vehicular LCF
500,000 Metric Tons of UF₄											
30	Truck	28,620	0.06	0	0.03	0.2	0	0.1	1	0	0.7
	Rail	10,480	0.02	0	0.008	0.04	0	0.03	0.1	0	0.2
55	Truck	26,760	0.05	0	0.03	0.2	0	0.1	1	0	0.6
	Rail	9,920	0.01	0	0.007	0.03	0	0.03	0.09	0	0.1
630,000 Metric Tons of UF₄											
30	Truck	36,025	0.07	0	0.04	0.3	0	0.2	1	0	0.8
	Rail	13,100	0.03	0	0.01	0.05	0	0.04	0.2	0	0.2
55	Truck	33,700	0.06	0	0.04	0.2	0	0.2	0	0	0.8
	Rail	12,500	0.02	0	0.009	0.03	0	0.04	0.1	0	0.2

^a Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

^b Radiological LCFs were estimated from the calculated doses by using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

^c Potential for irreversible adverse effects from chemical exposures.

TABLE 8.2 Total Risks from Accidents during Shipment of UF₄

Drum Size (gal)	Mode	Total Shipments ^a	Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
			Radiological LCF ^b	Chemical Effects ^c	Vehicular LCF	Radiological LCF ^b	Chemical Effects ^c	Vehicular LCF	Radiological LCF ^b	Chemical Effects ^c	Vehicular LCF
<i>500,000 Metric Tons of UF₄</i>											
30	Truck	28,620	0.0001	0.005	0.3	0.0004	0.02	1	0.002	0.1	6
	Rail	10,480	0.00001	0.001	0.1	0.00005	0.005	0.5	0.0002	0.03	2
55	Truck	26,760	0.0001	0.006	0.3	0.0004	0.02	1	0.002	0.1	5
	Rail	9,920	0.00001	0.001	0.1	0.00005	0.005	0.5	0.0002	0.03	2
<i>630,000 Metric Tons of UF₄</i>											
30	Truck	36,025	0.0001	0.007	0.4	0.0005	0.03	1	0.003	0.1	7
	Rail	13,100	0.00001	0.002	0.2	0.00006	0.007	0.6	0.0003	0.03	3
55	Truck	33,700	0.0001	0.007	0.3	0.0005	0.03	1	0.003	0.1	7
	Rail	12,500	0.00001	0.002	0.1	0.00006	0.007	0.6	0.0003	0.03	3

^a Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

^b Radiological LCFs were estimated from the calculated doses by using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., $1 \div 0.0004$).

^c Potential for irreversible adverse effects from chemical exposures.

TABLE 8.3 Potential Consequences to the Population from Severe Accidents during Shipment of UF₄

Type of Risk	Drum Size (gal)	Mode	Neutral Weather Conditions			Stable Weather Conditions		
			Rural	Suburban	Urban	Rural	Suburban	Urban
Radiological (LCFs) ^a	30	Truck	0.09	0.09	0.2	0.2	0.2	0.5
		Rail	0.3	0.2	0.5	0.6	0.6	1
	55	Truck	0.1	0.1	0.2	0.2	0.2	0.5
		Rail	0.3	0.3	0.6	0.7	0.6	1
Chemical (no. of persons) ^b	30	Truck	0.15	18	40	0.94	110	250
		Rail	0.45	54	120	2.3	270	610
	55	Truck	0.16	20	44	1	120	270
		Rail	0.46	55	120	2.4	290	650

^a Radiological risks of latent cancer fatalities (LCFs) were estimated from the calculated doses by using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., $1 \div 0.0004$).

^b Chemical risks were measured as the number of persons with potential for irreversible adverse effects. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997). Therefore, one fatality may be expected from chemical effects due to a severe accident involving a railcar in an urban environment under stable weather conditions.

TABLE 8.4 Potential Consequences to the MEI from Severe Accidents during Shipment of UF₄

Drum Size (gal)	Mode	Accident Risk			
		Neutral Weather Conditions		Stable Weather Conditions	
		Radiological Risk of LCF ^a	Chemical Effects ^b	Radiological Risk of LCF ^a	Chemical Effects ^b
30	Truck	0.004	Yes	0.06	Yes
	Rail	0.01	Yes	0.2	Yes
55	Truck	0.004	Yes	0.06	Yes
	Rail	0.01	Yes	0.2	Yes

^a Lifetime risk of LCF for an individual was estimated from the calculated doses by using a dose-to-risk conversion factor of 5×10^{-4} fatality per person-rem for members of the general public, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,000 (i.e., $1 \div 0.0005$).

^b Yes or no applies to the effect of chemical exposure on the MEI. There is no probability estimate; either there would or would not be an irreversible adverse effect.

TABLE 8.5 Consequences to the MEI during Routine Shipment of UF₄

Drum Size (gal)	Mode	Routine Radiological Risk from Single Shipment (lifetime risk of LCF) ^a				
		Inspector	Resident	Person in Traffic	Person at Gas Station	Person near Rail Stop
30	Truck	6×10^{-8}	8×10^{-12}	2×10^{-7}	1×10^{-8}	NA ^b
	Rail	7×10^{-8}	1×10^{-11}	2×10^{-7}	NA	7×10^{-10}
55	Truck	6×10^{-8}	7×10^{-12}	2×10^{-7}	1×10^{-8}	NA
	Rail	7×10^{-8}	9×10^{-12}	2×10^{-7}	NA	5×10^{-10}

^a Lifetime risk of LCF for an individual was estimated from the calculated dose by using the dose-to-risk conversion factor of 0.0005 fatality per person-rem for members of the general public, as recommended in ICRP Publication 60 (ICRP 1991). The corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the risk of LCF by 2,000 (i.e., $1 \div 0.0005$).

^b NA = not applicable.

Impacts from a potential severe accident could lead to fatalities from both radiological and chemical effects. Up to 1 potential LCF from radiological hazards is estimated for a rail accident occurring in an urban population zone under stable weather conditions. On the basis of chemical toxicity effects for the same conditions, up to 650 persons could be affected by irreversible adverse effects. Exposure to HF or uranium compounds was estimated to result in death to approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997). Therefore, one fatality may be expected from chemical effects due to a severe accident involving a railcar in an urban environment under stable weather conditions. Note that the number of irreversible adverse effects is probably an overestimate, because the toxicity value for UF_4 , which is only slightly soluble, was not adjusted to account for lowered intake due to low solubility. Because of the lack of data on absorption of UF_4 , the toxicity value used essentially assumed the same uptake of UF_4 as would occur for uranyl fluoride, a soluble compound. Details on the toxicity values and adjustments for solubility are given in Appendix C, Section C.5.2.1, of the depleted UF_6 PEIS (DOE 1999).

The highest potential routine radiological exposure to an MEI, with an LCF risk of 2×10^{-7} , would be for a person stopped in traffic near a shipment for 30 min at a distance of 3.3 ft (1 m). Such an exposure would be approximately 2.5 times less than the exposure a person receives from natural sources in the course of 1 day.

9 PARAMETRIC ANALYSIS

The parametric analysis of the disposal options considered the environmental impacts of disposing of 25% and 50% of the 560,000 metric tons of depleted UF₆ inventory as UF₄, similar to the analyses conducted in Appendix K of the PEIS (DOE 1999). The intent of the parametric analysis was to show how the environmental impacts calculated for the 100% cases would be affected by reductions in facility size and throughput. “Throughput” is a general term that refers to the amount of material handled or processed by a facility in a year. To simplify the analysis, only a subset of the disposal options was analyzed in detail; namely, the mine disposal of either 30-gal or 55-gal drums. A subset of options was selected because the relationships among the options within each category could be determined from the detailed analyses conducted for the 100% cases. Therefore, the results for the options analyzed in detail were used to estimate the impacts for the other options by comparison with the 100% cases.

For this analysis, it was assumed that the uranium material would be actively placed into disposal units over a 20-year period (from 2009 through 2028). The assessment considered the environmental impacts that would occur during (1) construction of a disposal facility, (2) routine disposal facility operations, (3) potential disposal facility accidents, and (4) the post-closure phase, defined as 1,000 years in the future after the disposal facility had failed. The areas of impact and the methodologies used to evaluate the parametric cases were the same as those used to evaluate the 100% cases. The supporting engineering data for the 25% and 50% parametric cases are provided in the engineering analysis report (Folga and Kier 2001).

9.1 HUMAN HEALTH — NORMAL OPERATIONS

9.1.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from the normal operation of a full-scale (100%) disposal facility are described in Sections 6 and 7. Similar impacts were calculated for the 50% and 25% disposal facilities for the parametric analysis. Radiological impacts were calculated for the operational phase (the phase during which material would be disposed of) and the post-closure phase (assumed to be 1,000 years in the future after the disposal facility failed).

9.1.1.1 Operational Phase

The radiological impacts estimated for the 100%, 50%, and 25% cases during the operational phase are shown in Figures 9.1 to 9.4 for involved workers. The impacts have been

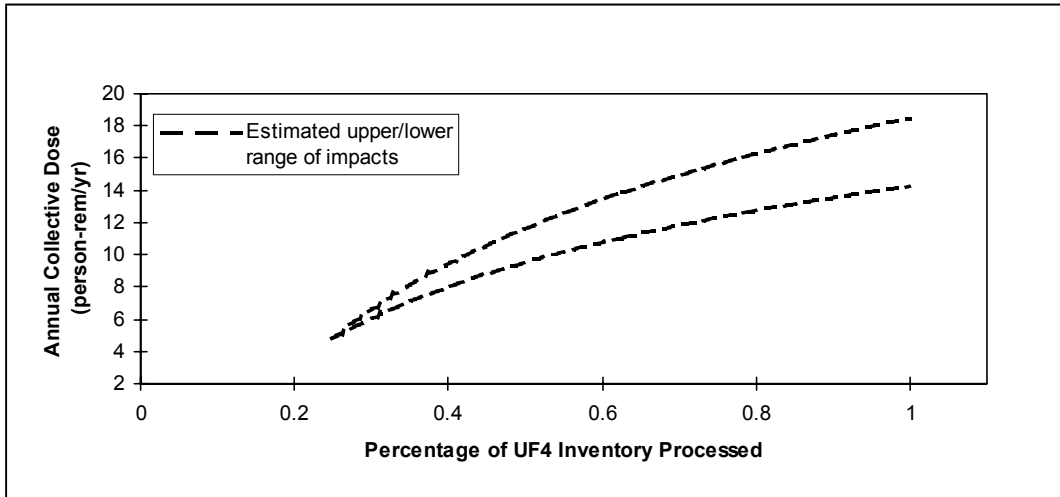


FIGURE 9.1 Estimated Annual Collective Dose to Involved Workers from the Disposal of 30-Gallon Drums (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

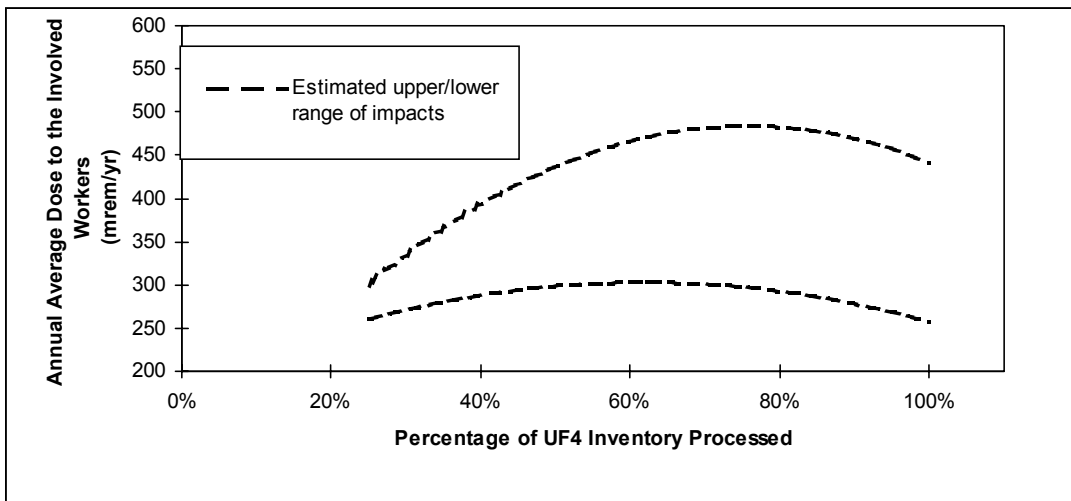


FIGURE 9.2 Estimated Annual Average Individual Dose to Involved Workers from the Disposal of 30-Gallon Drums (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

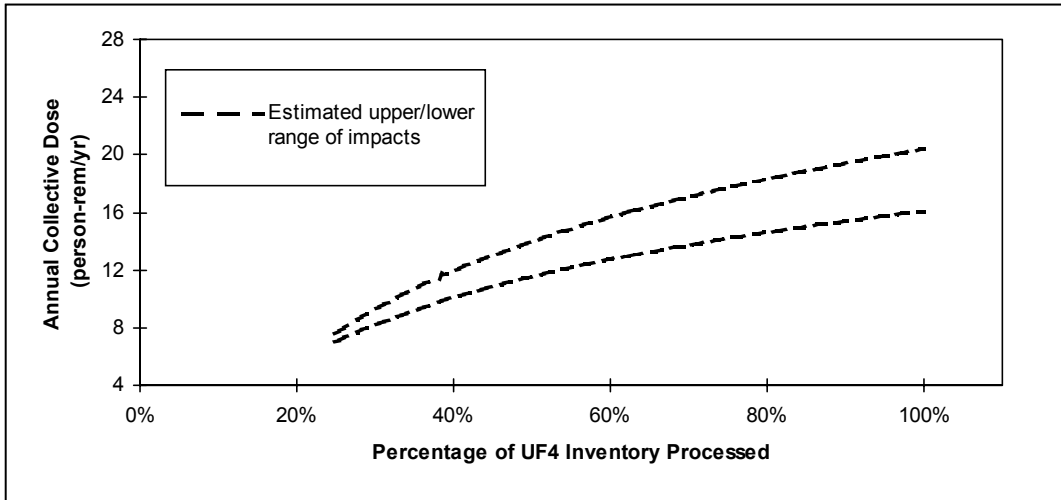


FIGURE 9.3 Estimated Annual Collective Dose to Involved Workers from the Disposal of 55-Gallon Drums (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

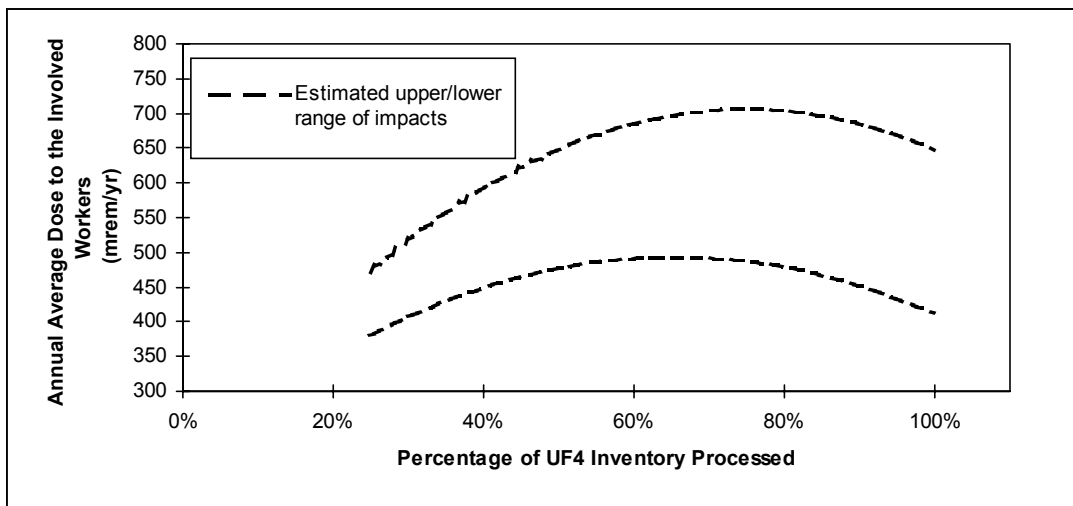


FIGURE 9.4 Estimated Annual Average Individual Dose to Involved Workers from the Disposal of 55-Gallon Drums (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

presented for the disposal of both 30-gal and 55-gal drums as a function of the amount of material requiring disposal. The range of impacts resulting from technology differences are presented by dashed lines in the figures. The area enclosed by the dashed lines indicates the range of impacts expected for throughputs between 25% and 100%, taking into account technology differences.

The disposal of UF_4 would not result in any airborne or waterborne emissions during operations. Therefore, no impacts on the noninvolved workers and the general public would be expected.

In general, the results of the parametric analysis (as shown in Figures 9.1 through 9.4) indicate that the collective radiological impacts during the operational phase would decrease with the total quantity of depleted uranium disposed of. The impacts from the 25% and 50% cases would be smaller than those from the 100% case, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts from the 50% case would be greater than half of the impacts from the 100% case). Overall, radiation doses from the disposal of 55-gal drums would be larger than those from disposal of 30-gal drums because of the greater dose rate associated with the larger containers. In some cases, the average individual worker dose might increase or decrease as the throughput increased, primarily because the number of workers required would not increase at the same rate as would the collective dose. The doses shown in the figures can be converted to the number (or risk) of LCFs by multiplying the doses (in rem or person-rem) by 0.0004 LCF/person-rem for workers.

9.1.1.2 Post-Closure Phase

At some time in the future after the closure of the disposal facility, impacts could occur to the public through the use of contaminated groundwater and from external radiation if the cover materials eroded away. In general, the complete erosion of the cover material, especially for a vault or mine, would not occur until thousands of years after the facility had been closed. Therefore, external radiation exposures would not be expected within the time frame considered (i.e., 1,000 years). Even if complete erosion occurred, the radiation exposure could be reduced by adding new cover material. Groundwater contamination would not be expected to occur until hundreds to thousands of years after the disposal facility had been closed. The estimated groundwater concentrations and associated uncertainty are discussed in Section 7.1. For assessment purposes, the MEI was assumed to live at the edge of the disposal site and to use groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. The potential radiation doses from using contaminated groundwater were based on groundwater concentrations calculated in the groundwater analysis that is discussed in detail in Section 7.2.

The estimates of the radiological impacts during the post-closure phase for disposal of 100% of the inventory were very small (i.e., less than 3×10^{-6} mrem/yr) within 1,000 years of facility

failure. Therefore, potential radiation exposures would be even smaller for the 25% and 50% parametric cases because a smaller inventory would be involved.

9.1.2 Chemical Impacts

9.1.2.1 Operational Phase

The estimated impacts from chemical exposures during the normal operation of full-scale (100%) disposal facilities are described in Section 6.1.2. The results of the 100% case analyses for the operational phase indicated that noninvolved workers and members of the general public would receive essentially no exposures to chemicals from the disposal of UF₄ because releases to the environment would be minimal. No adverse health impacts would be expected for any of the disposal facilities considered. Therefore, by comparison with the 100% case results, no adverse health impacts from chemical exposures would be expected for throughput rates between 25% and 100% for all disposal options.

9.1.2.2 Post-Closure Phase

As for radiological impacts, potential chemical impacts could occur to the general public at some time in the future through use of contaminated groundwater. The potential chemical impacts on an MEI from using contaminated groundwater were determined on the basis of the same assumptions discussed in Section 7.1.1 for radiological exposures. Chemical exposures were calculated for a time 1,000 years after the disposal facility was assumed to fail. Because of the low precipitation rate in a dry location, no chemical impacts would be expected within 1,000 years after failure for either the 25% or 50% parametric case.

9.2 HUMAN HEALTH — ACCIDENT CONDITIONS

9.2.1 Radiological and Chemical Impacts

The estimated accident impacts (radiation doses and LCFs) from potential accidents during operation of full-scale (100%) disposal facilities are presented in Sections 6.2.1 and 6.2.2. The analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented only for those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are

defined in the engineering analysis report (Folga and Kier 2001) for the 25% and 50% throughput cases.

On the basis of the assessment of the 25% and 50% disposal cases, the accident impacts associated with each of the parametric cases would be the same as those presented for the 100% cases. The impacts would be identical because the bounding accidents producing the greatest consequences within each frequency category would be the same for the 100%, 50%, and 25% cases. The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. However, as a result of the reduced throughput rates, the actual frequencies of some accidents related to handling operations (i.e., the “mishandle/drop of drum” accident) would decrease as the number of containers being handled would decrease. The resulting risk of these accidents would also decrease as their frequencies would decrease. However, none of the accident frequencies would change enough to cause the accident to be placed in a different frequency category. Therefore, the overall impacts associated with the disposal options would be the same for all parametric cases.

9.2.2 Physical Hazards

The estimated health impacts, such as on-the-job injuries and fatalities, from potential physical accidents during the construction and operation of full-scale (100%) disposal facilities are presented in Section 6.2.3. For the 100% analysis for mines, no on-the-job fatalities were estimated during construction and operation of a disposal facility for either 30-gal or 55-gal drums. The predicted number of on-the-job worker injuries for the 30-gal 100% case was about 300; the number of injuries for the 55-gal drum 100% case was estimated to be about 260. The impacts of the 25% and 50% cases would be smaller than those for the 100% case, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than 50% of the impacts for the 100% case).

The predicted number of on-the-job worker fatalities over the duration of disposal operations for both the 30-gal and 55-gal drum options would be less than 1, ranging from 0.3 for the 25% case to 0.67 for the 100% case (including construction and operations). The predicted number of on-the-job injuries (including construction and operations) would range from 150 to 300. The number of injuries for the 30-gal drum option is shown as a function of throughput in Figure 9.5; the values for the 55-gal drum option are shown in Figure 9.6.

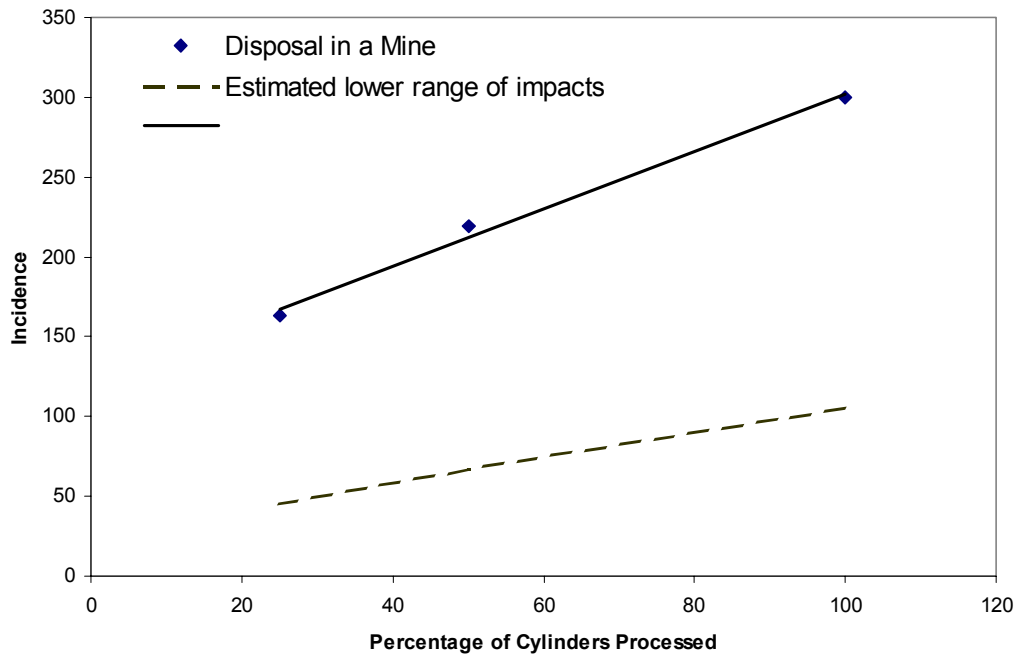


FIGURE 9.5 Estimated Number of on-the-Job Injuries (for entire construction and operational periods) from the Disposal of UF₄ in 30-Gallon Drums (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, or mine.)

9.3 AIR QUALITY

The estimated impacts on air quality during construction and operation of full-scale disposal facilities are presented in detail in Section 6.3. For parametric analysis, only the construction and operation emissions for the wasteform facility and mine are considered. All of the pollutant emissions generated during disposal would be well below their respective air quality standards. As indicated in Section 6.3, during construction for mines, concentration increments of PM₁₀ might be as high as 27% of the air quality standards. During operations for vaults, concentration increments of NO_x would be less than 11% of the air quality standards.

The air quality impacts calculated for the 50% and 25% parametric cases, on the basis of the information provided in the engineering analysis report (Folga and Kier 2001), were found to be less than those for 100% cases. During construction, emissions for the 50% and 25% cases when compared with the 100% case would range from 43 to 64% and from 30 to 46%, respectively. Resultant concentration increments would therefore be well below the standard. During operations, emissions for the 50% and 25% cases when compared with the 100% case would range from 42 to 79% and from 27 to 66%, respectively. Accordingly, potential air quality impacts would be expected to be minor, as they would be for the case of the full-scale facility.

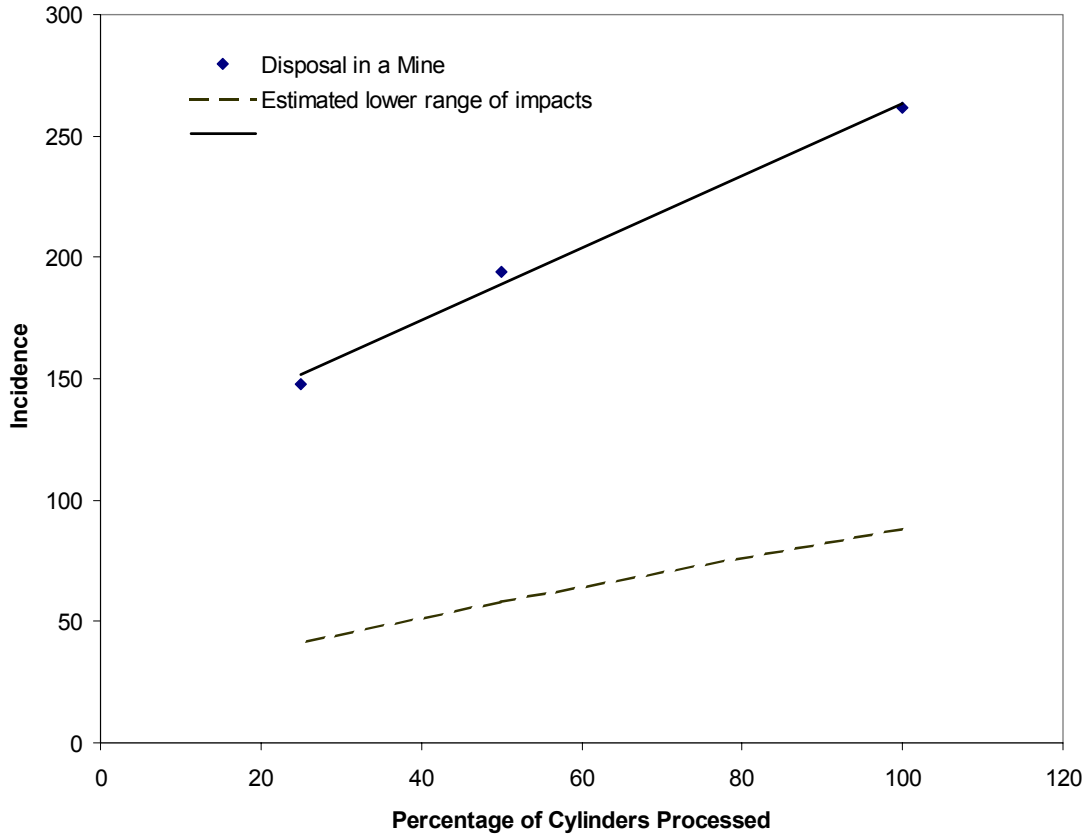


FIGURE 9.6 Estimated Number of on-the-Job Injuries (for entire construction and operational periods) from the Disposal of UF_4 in 55-Gallon Drums (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, or mine.)

9.4 WATER AND SOIL

9.4.1 Surface Water

The estimated impacts on surface water during construction, operations, and potential accidents for full-scale (100%) disposal facilities are discussed in Section 6.4. The actual impacts on surface water would depend on the ultimate site selected for disposal. However, for the generic sites considered, the impacts on surface water for the 100% case would be negligible for all disposal options for both the operational and post-closure phases. The impacts calculated for the 25% and 50% parametric cases, on the basis of information provided in the engineering analysis report (Folga and Kier 2001), would be less than those for the 100% case, and thus would also be negligible.

9.4.2 Groundwater

The actual impacts on groundwater would depend on the ultimate site selected for disposal. However, during the operational phase, which would include construction and disposal activities, impacts on groundwater would be expected to be negligible. As described in Section 6.4, the impacts on groundwater from the 100% case would be expected to be negligible for the operational phase of all disposal options.

Impacts on groundwater during the post-closure phase are discussed in Section 7.3. Groundwater impacts during the post-closure phase would be limited to changes in quality caused by contamination migrating from the disposal facility hundreds to thousands of years in the future after failure of the engineered barriers. There would be no impacts on effective recharge, depth to groundwater, or flow direction once the facility was constructed.

If the disposal site was located in a dry environment, all of the resulting uranium concentrations in groundwater would be very low for at least 1,000 years in the future for disposal of 25%, 50%, and 100% of the uranium material. Uranium concentrations would be well below the EPA proposed maximum contaminant level of 20 : g/L (EPA 1996) used as a guideline in the PEIS.

9.4.3 Soil

The estimated impacts on soil during construction, operations, and potential accidents for full-scale (100%) disposal facilities are presented in Section 6.4. The potential impacts evaluated included changes in topography (land elevation), permeability (ability to let water enter the ground), quality, and erosion potential for a dry location.

The impacts on soil from the 100% cases would be potentially moderate to large, but temporary, for the disposal options. These impacts would result from material excavated during disposal facility construction that would be left on site. For example, construction of a mine would require excavating a large amount of consolidated material. In the short term, this amount of material would cause changes in site topography. In the long term, contouring and reseeded would return soil conditions to their former state, and the impacts would be minor. The impacts calculated for the 25% and 50% parametric cases, on the basis of information provided in the engineering analysis report (Folga and Kier 2001), were also found to have potentially large, but temporary, impacts on soil, similar to the 100% cases. In the long term, impacts on soil would be minor for all disposal options.

9.5 SOCIOECONOMICS

Construction of a 50%-size wasteform facility for disposal in 30-gal containers would create 50 direct jobs and \$2.1 million in direct income (Table 9.1). Disposal in 55-gal containers would create 40 direct jobs and \$1.5 million in direct income. Operation of the wasteform facility would create 30 direct jobs and produce \$1.5 million in direct income if 30-gal containers were used, and 30 direct jobs and \$1.3 million if 55-gal containers were used. For the 25% facility, construction of the wasteform facility would create 30 direct jobs and \$1.2 million in direct income if 30-gal containers were used. Disposal in 55-gal containers would create 30 direct jobs and \$1.1 million in direct income. Operation of the wasteform facility would create 20 direct jobs and produce \$1.1 million in direct income if 30-gal containers were used, and 20 direct jobs and \$1.0 million if 55-gal containers were used.

TABLE 9.1 Socioeconomic Impacts from UF₄ Disposal Options: Parametric Analysis

UF ₄ Disposal Option and Socioeconomic Parameter	50% Case per Activity and Drum Size				25% Case per Activity and Drum Size			
	Construction ^a		Operations ^b		Construction ^a		Operations ^b	
	30-gal	55-gal	30-gal	55-gal	30-gal	55-gal	30-gal	55-gal
Wasteform facility								
Direct employment ^c (no. of persons)	50	40	30	30	30	30	20	20
Direct income (10 ⁶ year 2000 \$)	2.1	1.5	1.5	1.3	1.2	1.1	1.1	1.0
Mine								
Direct employment ^c (no. of persons)	580	520	20	20	440	400	10	10
Direct income (10 ⁶ year 2000 \$)	19.4	17.4	1.1	1.0	14.8	13.4	0.8	0.7

^a Impacts in the peak year of construction: Year 3 for the wasteform facility, Year 5 or 6 for the mine. Construction impacts from the shallow earthen structure and vault are identical in each year of the life of the facility, with construction continuing concurrently with waste placement.

^b Impacts are for the first year of operation.

^c For operations, direct employment includes those persons directly associated with operations, such as chemical operators, foremen, and technicians, plus their line supervision. Clerical and health physics support is also included. The values presented here represent the estimated number of workers for a “greenfield” site, where a new disposal facility would be constructed in support of depleted UF₄ disposal. The number of additional workers that would be required at an already existing disposal site would, in general, be less than those shown above.

Construction of a 50%-size mined cavity for disposal in 30-gal containers would create 580 direct jobs and \$19.4 million in direct income. Disposal in 55-gal containers would create 520 direct jobs and \$17.4 million in direct income. Operation of the mined cavity would create 20 direct jobs and produce \$1.1 million in direct income if 30-gal containers were used, and 20 direct jobs and \$1.0 million if 55-gal containers were used. For a 25% facility, construction of the mined cavity would create 440 direct jobs and \$14.8 million in direct income if 30-gal containers were used, and 400 direct jobs and \$13.4 million in direct income if 55-gal containers were used. Operation of the mined cavity would create 10 direct jobs and produce \$0.8 million in direct income if 30-gal containers were used, and 10 direct jobs and \$0.7 million if 55-gal containers were used.

9.6 ECOLOGY

Site preparation for the construction of a facility for the disposal of UF_4 would result in the disturbance of biotic communities, including the permanent replacement of habitat with structures and paved areas. Existing vegetation would be destroyed during land-clearing activities. Wildlife would be disturbed by land clearing, noise, and human presence.

This disposal option would result in elevation of the soil surface and a reduction in soil permeability. The excavated material would primarily consist of rock removed from the drifts and ramps. The consequent decrease in surface soil moisture would make reestablishment of vegetation difficult and delay the establishment of native plant communities. Construction of a disposal facility for UF_4 in a mine could result in a large adverse impact on existing vegetation and wildlife.

Impacts on wetlands and state and federally protected species due to facility construction would depend on facility location. Avoidance of wetland areas would be part of facility planning. Site-specific surveys for protected species would be conducted before finalization of facility siting plans. Impacts on air, surface water, groundwater, and soil quality during construction would be expected to be negligible for the 25%, 50%, and 100% cases. Resulting construction-derived impacts on ecological resources would also be expected to be negligible. Impacts on ecological resources from air and water emissions would also be negligible during the operational phase of the disposal options.

During the post-closure phase, failure of facility integrity could result in contamination of groundwater. Groundwater could discharge to the surface (such as in wetland areas), thus exposing biota to contaminants. For the 100% cases, groundwater concentrations of uranium calculated for 1,000 years after failure of a mined facility would be well below levels expected to cause adverse impacts on aquatic biota. Groundwater uranium concentrations for the 25% and 50% cases would be lower, and resulting impacts on aquatic biota, therefore, would be negligible.

9.7 WASTE MANAGEMENT

The estimated impacts from waste management operations during the construction and operation of full-scale (100%) disposal facilities are discussed in detail in Section 6.7. The impacts on national waste management operations from construction of disposal facilities were found to be negligible for the 100% throughput case. The impacts that would result from construction and operation for the 25% and 50% parametric cases, on the basis of information provided in the engineering analysis report (Folga and Kier 2001), would be less than those for the 100% case, and thus would also be negligible.

9.8 RESOURCE REQUIREMENTS

The estimated impacts from resource requirements during construction and operation of full-scale (100%) disposal facilities are presented in detail in Section 6.8. The impacts on resources, except for electrical consumption for a mine disposal facility, would be expected to be small for the 100% capacity case. Resource requirements for the 25% and 50% parametric cases considered would be less than those for the 100% case (Folga and Kier 2001).

Construction and operation of the disposal facilities would consume an irretrievable amount of electricity, fuel, concrete, steel and other metals, water, and miscellaneous chemicals. The total quantities of commonly used materials would not be expected to be significant. The requirements for disposal facility operations would generally not be resource-intensive, and the resources required are not considered rare or unique.

Furthermore, committing any of these resources (except for electrical consumption) would not be expected to cause a negative impact on the availability of these resources within local areas or nationally for the 100%, 50%, and 25% cases. The magnitude of the impact from the large electricity requirement for a mine disposal facility on local energy resource usage would depend on the extent of existing site infrastructure.

9.9 LAND USE

Impacts from on-site disposal of excavated material during the construction and operation of a mine disposal facility would be expected to be moderate to large. Impacts on traffic volume would be associated with the construction labor force. On-site topographical modifications associated with disposition of the excavated material could potentially affect future on-site land use, although such impacts would be small.

By comparison with the parametric analysis for disposal in mines, land use impacts from disposal in a shallow earthen structure or vault would be expected to range from negligible to moderate. Impacts on land use outside the boundaries of a disposal facility would consist of temporary traffic impacts associated with project construction. The actual impacts would depend on the specific site chosen.

9.10 TRANSPORTATION

The estimated risks from the shipment of all the UF_4 from a conversion facility to a disposal site are presented in Section 8. The parametric risks for the UF_4 shipments are presented in Figures 9.7 and 9.8 for shipment by truck and rail, respectively. The radiological risks from accidents are not presented because these risks would be at least 50 times less than the other estimated risks.

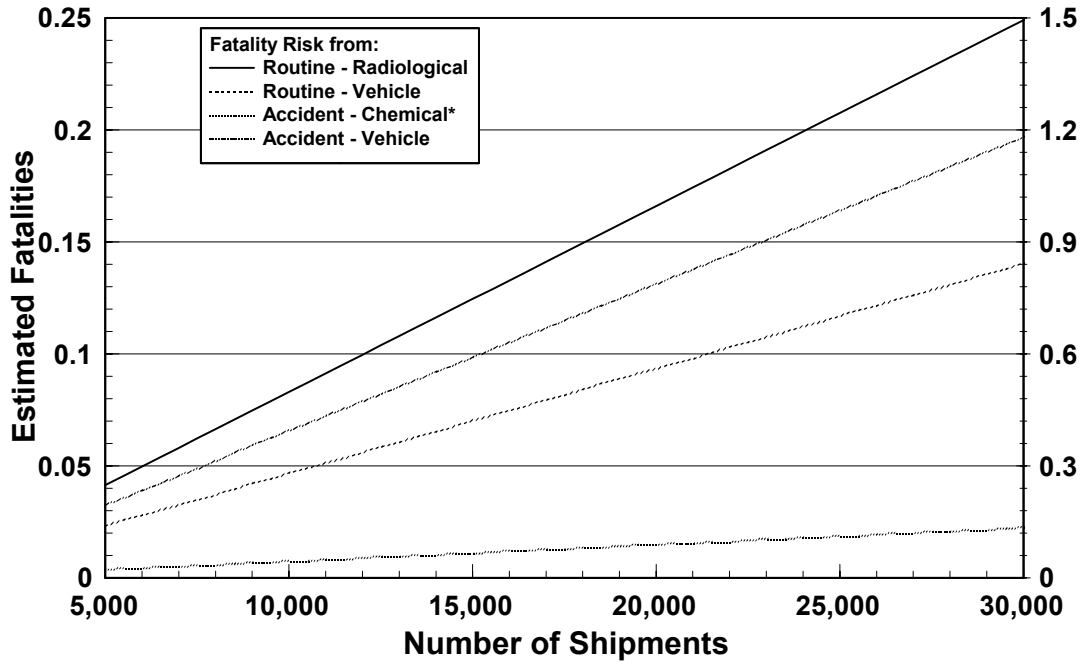


FIGURE 9.7 Estimated Truck Transportation Risks from Shipping UF₄ from the Conversion Facility to Disposal

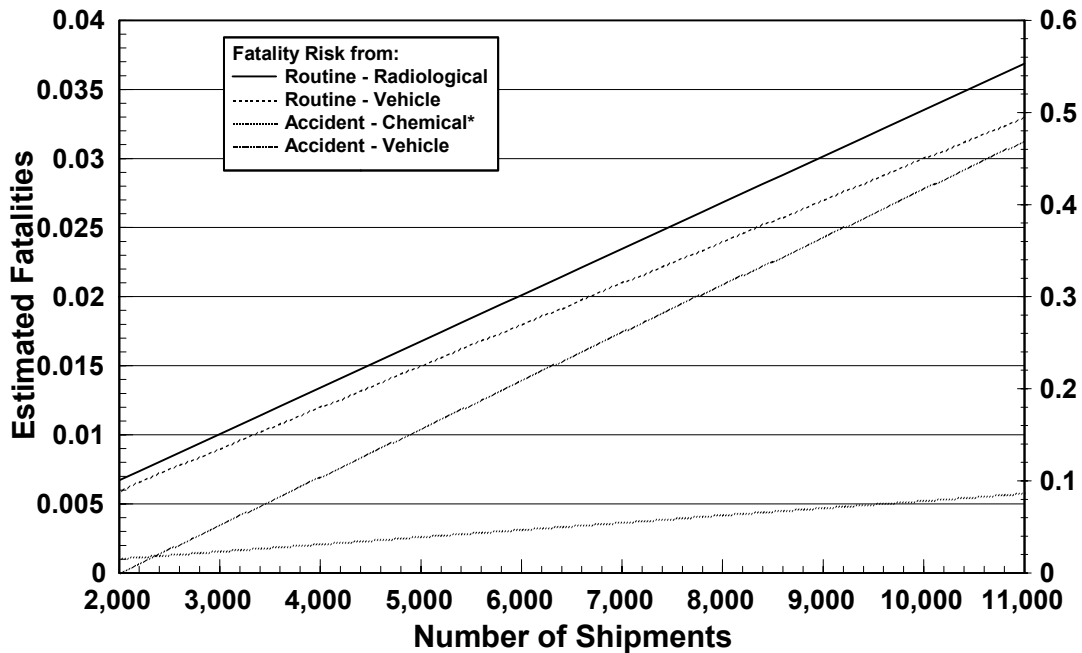


FIGURE 9.8 Estimated Rail Transportation Risks from Shipping UF₄ from the Conversion Facility to Disposal

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