LES Exhibit 18

"Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Mgmt. and use of Depleted Uranium Hexafluoride" (DOE/EIS-0269), Vols. 1 and 2

DOE/EIS-0269

FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR ALTERNATIVE STRATEGIES FOR THE LONG-TERM MANAGEMENT AND USE OF DEPLETED URANIUM HEXAFLUORIDE

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TITLE: Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride (DOE/EIS-0269)

CONTACT: For further information on this Programmatic Environmental Impact Statement (PEIS), call or contact:

Scott E. Harlow
Office of Nuclear Facilities Management (NE-40)
Office of Nuclear Energy, Science and Technology
U.S. Department of Energy
19901 Germantown Road
Germantown, MD 20874
301-903-3352

For general information on the DOE NEPA process, call 1-800-472-2756 to leave a message or contact:

Carol Borgstrom, Director
Office of NEPA Policy and Assistance (EH-42)
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585
202-586-4600

ABSTRACT: This PEIS assesses the potential impacts of alternative management strategies for depleted uranium hexafluoride (UF_6) currently stored at three DOE sites: Paducah site near Paducah, Kentucky; Portsmouth site near Portsmouth, Ohio; and K-25 site on the Oak Ridge Reservation, Oak Ridge, Tennessee. The alternatives analyzed in the PEIS include no action, long-term storage as UF_6, long-term storage as uranium oxide, use as uranium oxide, use as uranium metal, and disposal. DOE's preferred alternative is to begin conversion of the depleted UF_6 inventory as soon as possible, either to uranium oxide, uranium metal, or a combination of both, while allowing for use of as much of this inventory as possible.

* Vertical lines in the right margin of this cover sheet and the notation list, summary, and Chapters 1 through 11 indicate changes that have been added after the public comment period.

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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

AIHA	American Industrial Hygiene Association
AQCR	Air Quality Control Region
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
BEA	U.S. Bureau of Economic Analysis
CAAA	*Clean Air Act Amendments*
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act* of 1980
CFR	*Code of Federal Regulations*
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	environmental assessment
EBE	evaluation basis earthquake
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERPG	Emergency Response Planning Guide
FFA	Federal Facilities Agreement
FFCA	*Federal Facilities Compliance Act* of 1992
FR	*Federal Register*
HAP	hazardous air pollutant
HLW	high-level radioactive waste
ICRP	International Commission on Radiological Protection
KAR	*Kentucky Administrative Regulations*
KDEP	Kentucky Department of Environmental Protection
KPDES	Kentucky Pollutant Discharge Elimination System
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLMW	low-level mixed waste
LLW	low-level radioactive waste
LMES	Lockheed Martin Energy Systems, Inc.
MCL	maximum contaminant level
MEI	maximally exposed individual
MMES	Martin Marietta Energy Systems, Inc.

MOA	memorandum of agreement
NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection and Measurements
NEPA	*National Environmental Policy Act* of 1969
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEIS	programmatic environmental impact statement
PEL	permissible exposure limit
PGDP	Paducah Gaseous Diffusion Plant
PM_{10}	particulate matter with a mean diameter of 10 μm or less
PUEC	Portsmouth Uranium Enrichment Complex
ROI	region of influence
RCRA	*Resource Conservation and Recovery Act*
SAR	safety analysis report
TDEC	Tennessee Department of Environment and Conservation
TSCA	*Toxic Substances Control Act*
USC	*United States Code*
USEC	United States Enrichment Corporation
USGS	U.S. Geological Survey
WM PEIS	*Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*

Chemicals

CaF_2	calcium fluoride
CO	carbon monoxide
HC	hydrocarbons
HF	hydrogen fluoride
MgF_2	magnesium fluoride
NH_3	ammonia
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
O_3	ozone
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
SO_2	sulfur dioxide
SO_x	sulfur oxides
SVOC	semivolatile organic compound

TCE	trichloroethylene
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_2F_2	uranyl fluoride
U_3O_8	triuranium octaoxide (uranyl uranate)
VOC	volatile organic compound

UNITS OF MEASURE

°C	degrees Celsius
°F	degrees Fahrenheit
Ci	curie(s)
cm	centimeter(s)
cm^3	cubic centimeter(s)
d	day(s)
ft	foot (feet)
ft^2	square foot (feet)
g	gram(s)
gal	gallon(s)
GWh	gigawatt hour(s)
h	hour(s)
ha	hectare(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
L	liter(s)
lb	pound(s)
µCi	microcurie(s)
µg	microgram(s)
µm	micrometer(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mg	milligram(s)
mi^2	square mile(s)
min	minute(s)
mL	milliliter(s)
mrem	millirem(s)
MVa	megavolt-ampere(s)
MW	megawatt(s)
pCi	picocurie(s)
ppb	part(s) per billion
ppm	part(s) per million
rem	roentgen equivalent man
s	second(s)
ton(s)	short ton(s)
yd^3	cubic yard(s)
yr	year(s)

ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS

In this document, units of measure are presented with the English unit first, followed in most cases by the metric equivalent in parentheses; if the measurement was originally made in metric units, the values were not converted back to English units. In tables, the data are expressed in one unit only. The following table lists the appropriate equivalents for English and metric units.

Multiply	By	To Obtain
English/Metric Equivalents		
acres	0.4047	hectares (ha)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
degrees Fahrenheit (°F) -32	0.5555	degrees Celsius (°C)
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
gallons (gal)	0.003785	cubic meters (m^3)
inches (in.)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
short tons (tons)	907.2	kilograms (kg)
short tons (tons)	0.9072	metric tons (t)
square feet (ft^2)	0.09290	square meters (m^2)
square yards (yd^2)	0.8361	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
yards (yd)	0.9144	meters (m)
Metric/English Equivalents		
centimeters (cm)	0.3937	inches (in.)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters (m^3)	1.308	cubic yards (yd^3)
cubic meters (m^3)	264.2	gallons (gal)
degrees Celsius (°C) +17.78	1.8	degrees Fahrenheit (°F)
hectares (ha)	2.471	acres
kilograms (kg)	2.205	pounds (lb)
kilograms (kg)	0.001102	short tons (tons)
kilometers (km)	0.6214	miles (mi)
liters (L)	0.2642	gallons (gal)
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
metric tons (t)	1.102	short tons (tons)
square kilometers (km^2)	0.3861	square miles (mi^2)
square meters (m^2)	10.76	square feet (ft^2)
square meters (m^2)	1.196	square yards (yd^2)

1 INTRODUCTION

The U.S. Department of Energy (DOE) is analyzing strategies for the long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites near Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. DOE has determined that the selection and implementation of a long-term management strategy for depleted UF_6 is a major federal action with the potential to significantly affect the natural and human environment; thus, preparation of an environmental impact statement (EIS) is required. Because selection of a management strategy is a broad agency action setting the course of a program, this EIS is a programmatic EIS (PEIS). It describes alternative strategies (including current management, storage, use, and disposal) that could be employed in the long-term management of depleted UF_6 and analyzes the potential environmental consequences of implementing each alternative strategy for the period from 1999 through 2039. The PEIS has been prepared in accordance with the *National Environmental Policy Act* of 1969 (NEPA), as presented in the *United States Code* (42 USC 4321 et seq.), and applicable NEPA implementing regulations listed in the *Code of Federal Regulations* (40 CFR Parts 1500-1508 and 10 CFR Part 1021). It is anticipated that one or more follow-on NEPA reviews will be conducted after the Record of Decision for this PEIS to address site selection, technology selection, and facility construction and operation activities.

1.1 BACKGROUND INFORMATION

Uranium is the fuel used in most nuclear reactors and is also a component of nuclear weapons. Uranium is a naturally occurring radioactive element consisting of several isotopes: uranium-238 (99.3%), uranium-235 (0.7%), and uranium-234 (0.005%). These isotopes differ in the number of neutrons in their nuclei. The use of uranium for nuclear weapons and as a fuel in light water nuclear reactors, such as the reactors used to produce electricity in the United States, requires increasing the proportion of the uranium-235 isotope found in natural uranium through an isotopic separation process called enrichment. An enrichment process called gaseous diffusion is currently used in the United States.

The gaseous diffusion process requires uranium in the form of UF_6. UF_6 is a chemical compound consisting of one atom of uranium combined with six atoms of fluorine. It can be a solid, liquid, or gas, depending on its temperature and pressure. (See Appendix A of the PEIS for additional information on the properties of UF_6.) It is used for the gaseous diffusion process primarily because it can conveniently be used as a gas for processing, as a liquid for filling or emptying containers or equipment, and as a solid for storage. At atmospheric pressure, UF_6 is a solid below a temperature of 134°F (57°C) and a gas at temperatures above 134°F. Solid UF_6 is a white, dense, crystalline material that resembles rock salt. Liquid UF_6 is formed only at temperatures greater than 147°F (64°C) and at a pressure somewhat greater than atmospheric pressure.

UF_6 does not react with oxygen, nitrogen, carbon dioxide, or dry air, but it does react with water or water vapor. (For this reason, UF_6 is always handled in leaktight containers and processing equipment.) When UF_6 comes into contact with water, such as water vapor in the air, the UF_6 and water react, forming hydrogen fluoride (HF) and a uranium-fluoride compound called uranyl fluoride (UO_2F_2).

The characteristics of UF_6 pose potential health risks, and the material is handled accordingly. Uranium is radioactive, and UF_6 in storage emits low levels of gamma and neutron radiation. The radiation levels measured on the outside surface of filled depleted UF_6 storage cylinders are typically about 2 to 3 millirem per hour (mrem/h), decreasing to about 1 mrem/h at a distance of 1 ft (0.3 m). In addition, if UF_6 is released to the atmosphere, the uranium compounds and HF that are formed by reaction with moisture in the air can be chemically toxic. Uranium is a heavy metal that, in addition to being radioactive, can have toxic chemical effects (primarily on the kidneys) if it enters the bloodstream by means of ingestion or inhalation. HF is an extremely corrosive gas that can damage the lungs and cause death if inhaled at high enough concentrations. The potential health risks associated with these substances are discussed in further detail in Chapter 4, Sections 4.3.1 and 4.3.2.

The enrichment of uranium by gaseous diffusion requires several steps (Figure 1.1). In the first step, uranium oxide is extracted from natural uranium ore and sent to an industrial facility where it is combined with anhydrous HF and fluorine gas to form UF_6. The product UF_6 is placed into steel cylinders and shipped as a solid to a gaseous diffusion plant for enrichment. The gaseous diffusion process takes a stream of heated UF_6 gas and separates it into two parts, one "enriched" with uranium-235 (i.e., uranium that contains more than 0.7% uranium-235) and the other "depleted" of uranium-235 (i.e., uranium that contains less than 0.7% uranium-235). The enriched UF_6 is generally used to manufacture fuel for nuclear reactors. The depleted UF_6 is stored as a solid in large metal cylinders at the enrichment facility.

The first large-scale uranium enrichment effort in the United States began as part of the atomic bomb development by the Manhattan Project during World War II. Later, enrichment for both civilian and military uses continued under the auspices of the U.S. Atomic Energy Commission and its successor agencies, including DOE. Three large gaseous diffusion plants were constructed to produce enriched uranium, first at the K-25 site[1] on the Oak Ridge Reservation near Oak Ridge, Tennessee, and subsequently at the Paducah site near Paducah, Kentucky, and the Portsmouth site near Portsmouth, Ohio (Figure 1.2). The K-25 plant ceased operations in 1985; however, depleted UF_6 from past operations is currently stored there in large steel cylinders. Depleted UF_6 from past operations at the Paducah and Portsmouth sites is also stored at those two sites in cylinders.

Uranium is still enriched at the Paducah and Portsmouth sites by the United States Enrichment Corporation (USEC). In 1993, the U.S. government created USEC pursuant to the

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[1] The K-25 site is now called the East Tennessee Technology Park but is referred to as the K-25 site throughout this PEIS.

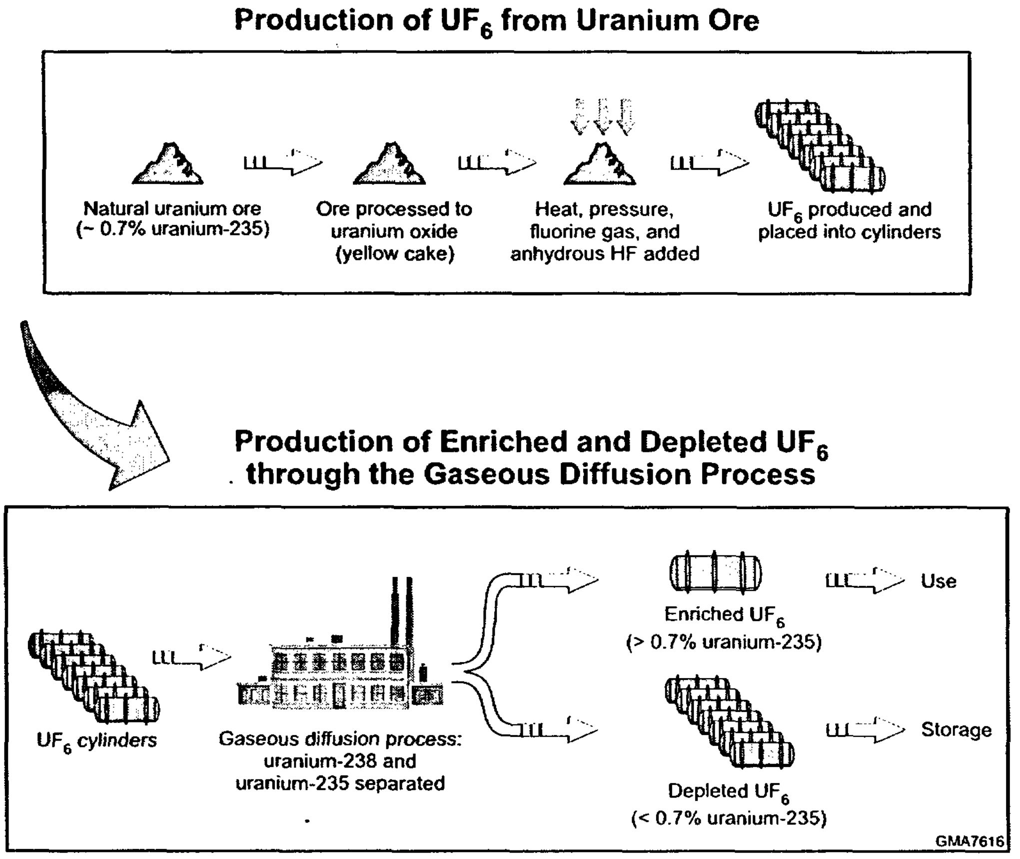

FIGURE 1.1 Schematic Depiction of UF_6 Production and Uranium Enrichment

Energy Policy Act of 1992 (Public Law 102-186) and began the process of privatizing the two operating gaseous diffusion plants. However, after the formation of USEC, DOE retained responsibility for 46,422 cylinders that contained depleted UF_6 produced before 1993 and were being stored at the three sites (28,351 at Paducah, 13,388 at Portsmouth, and 4,683 at K-25). The *USEC Privatization Act* (Public Law 104-134), signed into law on April 26, 1996, provides for the transfer of ownership of USEC from the government to private investors. This act provides for the allocation of USEC's liabilities between the U.S. Government (including DOE) and the new private corporation, including those liabilities for UF_6 cylinders generated by USEC before privatization. The allocation of responsibilities for this depleted uranium is described in a memorandum of agreement (MOA) between the USEC and DOE that was signed in May 1998 (DOE and USEC 1998a). This MOA transfers ownership of approximately 9,400 depleted UF_6 cylinders from USEC to DOE. A second MOA, signed in June 1998, transfers ownership of approximately 2,000 additional depleted UF_6 cylinders to DOE (DOE and USEC 1998b). The total cylinder inventory for which DOE currently has management responsibility consists of approximately 58,000 cylinders. (Additional details about the cylinder inventory are provided in Section 1.5.2).

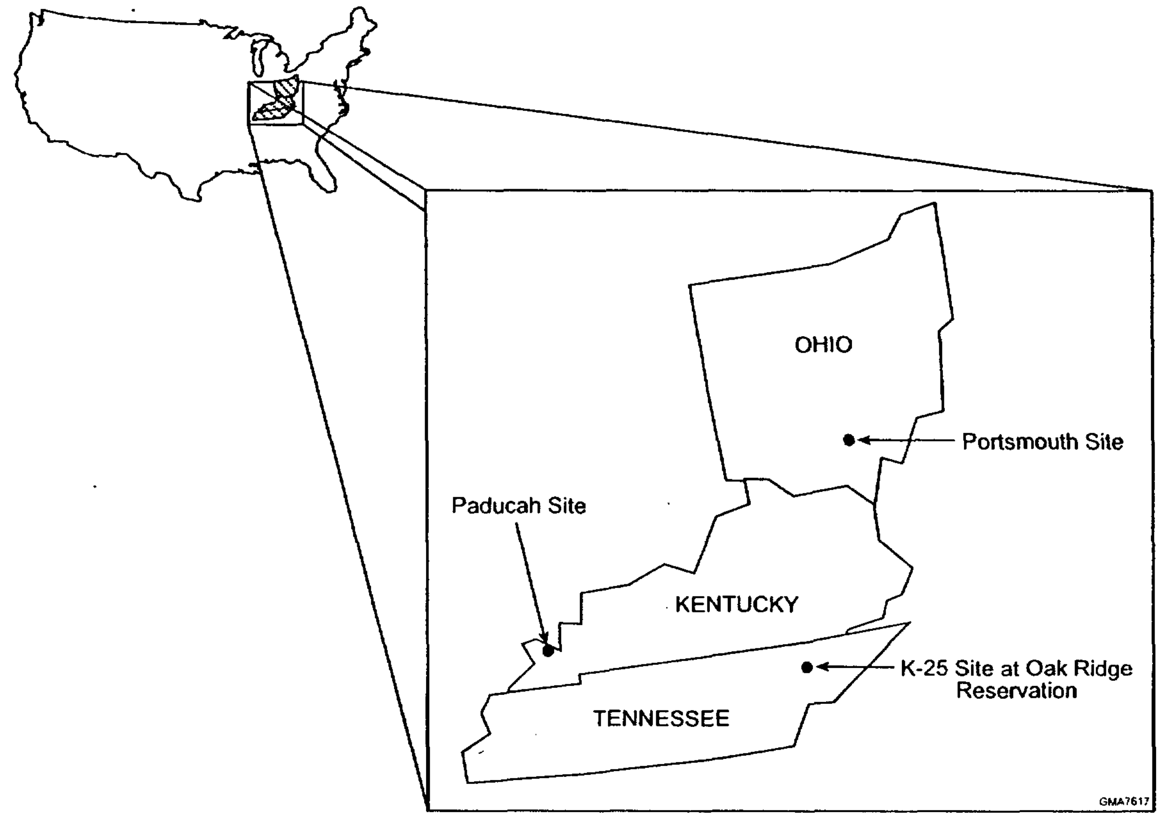

FIGURE 1.2 Depleted UF_6 Storage Locations

Depleted UF_6 has been stored at all three storage sites since the 1950s in large steel cylinders. Several different cylinder types are in use, although the vast majority of cylinders have a 14-ton (12-metric ton) capacity. Two typical cylinder types are shown in Figure 1.3. The 14-ton-capacity cylinders are 12 ft (3.7 m) long by 4 ft (1.2 m) in diameter, with most having a wall thickness of 5/16 in. (0.79 cm) of steel. The cylinders have external stiffening rings that provide support. Lifting lugs for handling are attached to the stiffening rings. A small percentage of the cylinders have skirted ends (extensions of the cylinder walls past the rounded ends of the cylinder), as shown in Figure 1.3. Each cylinder has a single valve for filling and emptying located on one end at the 12 o'clock position. Similar, but slightly smaller, cylinders with a capacity of 10 tons (9 metric tons) are also in use. Cylinders are manufactured in accordance with an American National Standards Institute standard (ANSI N14.1, *American National Standard for Nuclear Materials — Uranium Hexafluoride — Packaging for Transport*) as specified in 49 CFR 173.420, the federal regulations governing transport of depleted UF_6.

Cylinders are initially filled with liquid depleted UF_6, which is allowed to cool over several days. As the liquid UF_6 cools, it contracts, forming a solid that fills approximately 60% of the internal cylinder volume. During storage, a cylinder contains solid UF_6 in the bottom and UF_6 gas

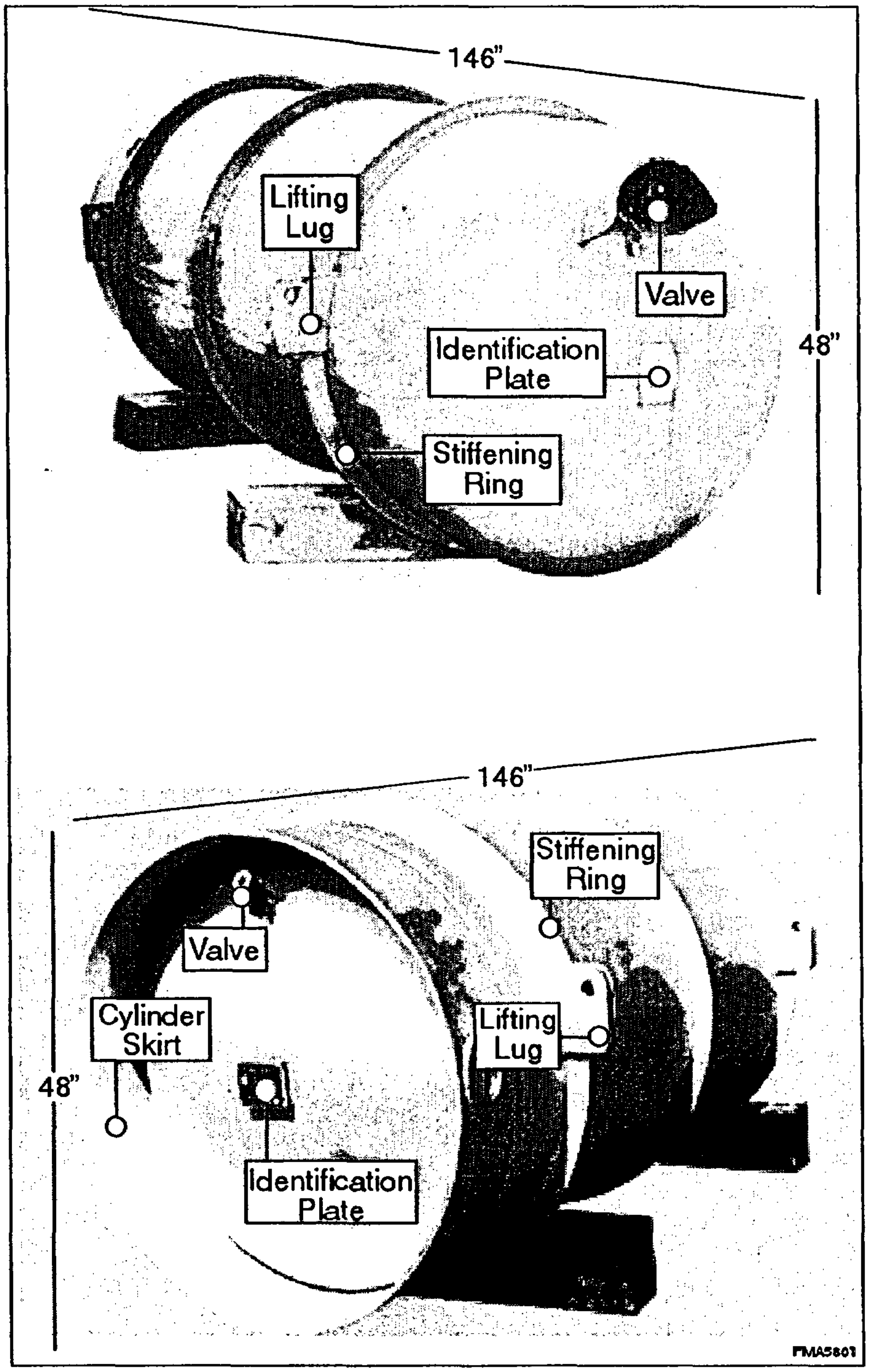

FIGURE 1.3 Typical Depleted UF_6 Storage Cylinders (Cylinders are constructed of steel, with the majority of cylinders having a 14-ton capacity. The bottom cylinder shows a "skirted" end.)

at less than atmospheric pressure in the top. The UF_6 inside the cylinder combines with the iron on the inner surfaces to form a surface layer of iron fluoride that inhibits internal corrosion. Because the pressure within the cylinders is less than atmospheric pressure, if a leak develops, air rushes into the cylinder until the pressure is equalized; UF_6 gas is not released initially, but HF gas is slowly released because moisture in the incoming air reacts with the UF_6.

The depleted UF_6 cylinders managed by DOE at the three sites are typically stacked two cylinders high in large areas called yards (Figure 1.4). Current management of this material requires safe storage, with minimum risks to workers, members of the general public, and the environment. Because storage began in the early 1950s, many of the cylinders now show evidence of external corrosion. Before 1998, seven cylinders (one at Paducah, two at Portsmouth, and four at K-25) had been identified to have developed holes (breaches), generally around spots previously damaged by handling activities. Because the depleted UF_6 is a solid at ambient temperatures and pressures, it is not readily released from a cylinder following a leak or "breach." When a cylinder is breached, moist air reacts with the exposed UF_6 solid and iron, resulting in the formation of a dense plug of solid uranium and iron compounds. The plug tends to block the breach for a period of time, so that release of uranium compounds and HF gas occurs very slowly. When the cylinder breaches are identified, either the breaches are repaired or the cylinder contents are transferred to new cylinders as soon as possible.

DOE maintains an active cylinder management program to improve storage conditions in the cylinder yards, monitor cylinder integrity, conduct routine inspections for breaches, and maintain and repair cylinders as needed. (Details of DOE's cylinder management program are provided in Appendix D.) In 1998, one additional cylinder breach occurred during the course of cylinder maintenance operations (i.e., cylinder painting); previous corrosion modeling had predicted that some additional cylinder breaches might be detected or occur during such activities. (Details on corrosion modeling predictions and breached cylinders are given in Appendix B.) The cylinder management program includes provisions for patching newly identified breached cylinders to eliminate releases of material.

DOE has responsibility for continued management of the depleted UF_6 cylinders stored at the Paducah, Portsmouth, and K-25 sites. The management plan in place during much of the preparation of this PEIS was to continue safe storage of the cylinders and, if no alternative uses for the depleted uranium were found to be feasible by about the year 2010, take steps to convert the UF_6 to triuranium octaoxide (U_3O_8) beginning in the year 2020. The U_3O_8, which is more chemically stable than UF_6, would be stored until there was a determination that all or a portion of the depleted uranium was no longer needed. At that point, the U_3O_8 would be disposed of as low-level radioactive waste (LLW). This plan was based on reserving depleted UF_6 for future defense needs and other potential productive and economically viable purposes, including possible reenrichment in an atomic vapor laser isotope separation plant, conversion of UF_6 to depleted uranium metal for fabrication of penetrators (anti-tank weapons) for military use, and use as fuel in advanced liquid metal nuclear reactors.[2]

[2] Further details of the former management plan are described in Sewell (1992).

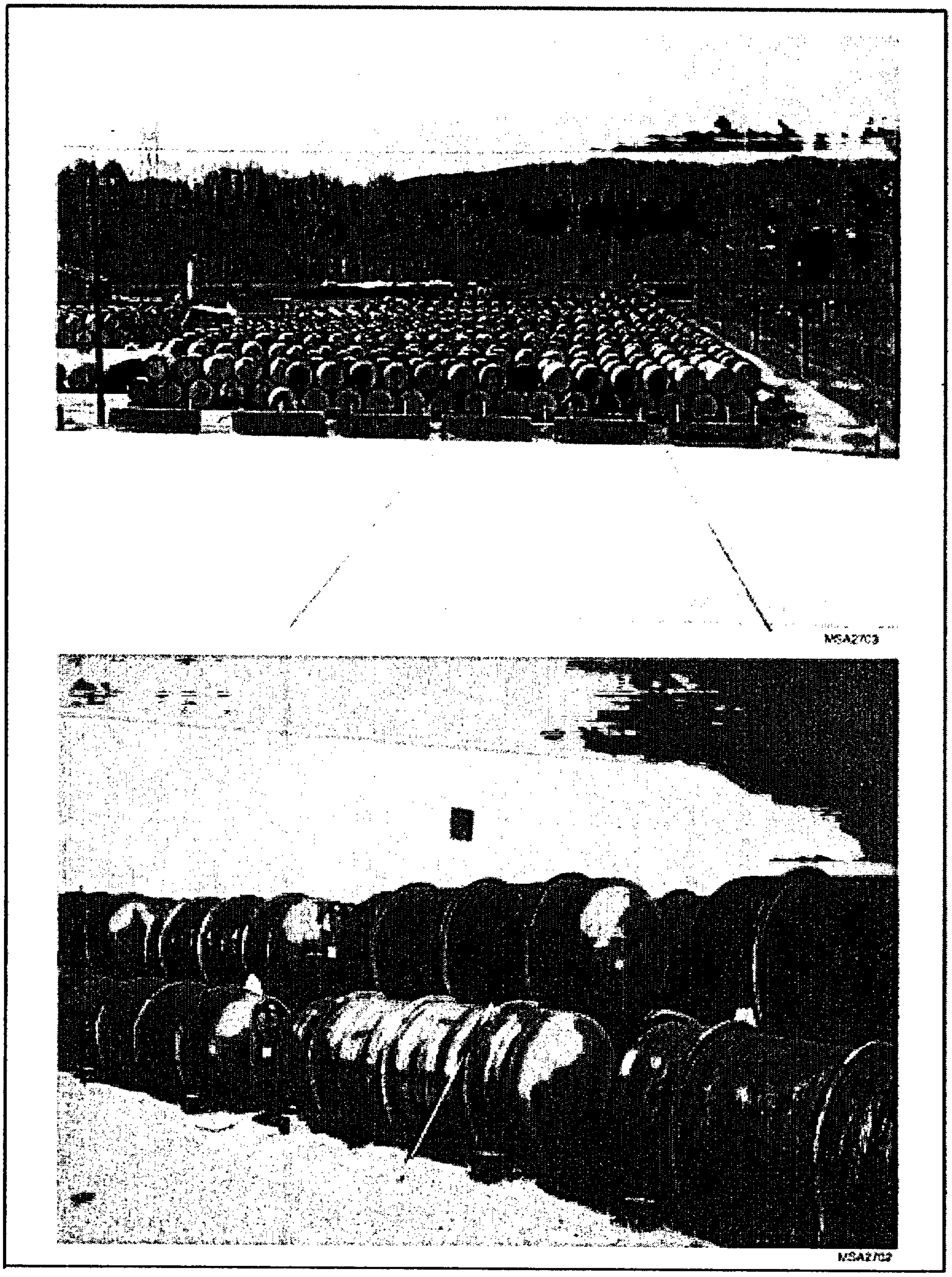

FIGURE 1.4 Depleted UF_6 Cylinders in Storage Yards

Since the former plan was put in place, several developments have occurred that suggest this plan should be revised. For example, the *Energy Policy Act of 1992* assigned responsibility for uranium enrichment and development of atomic vapor laser isotope separation to the USEC, the demand for penetrators has diminished, and the advanced liquid metal nuclear reactor program has been canceled. In addition, stakeholders near the current cylinder storage sites have expressed concerns regarding potential environmental, safety, health, and regulatory issues associated with the continued storage of the depleted UF_6 inventory. The Ohio Environmental Protection Agency issued a Notice of Violation to DOE (which has since been resolved), and the Defense Nuclear Facilities Safety Board (DNFSB) provided a recommendation to the Secretary of Energy regarding improvements in the management of depleted UF_6 (DNFSB 1995).

DOE also entered into a Consent Order with the Department of Environment and Conservation of the State of Tennessee with respect to the management of the depleted UF_6 stored at the K-25 site. DOE has agreed that if it chooses any action alternative as the outcome of this PEIS, it shall, subject to appropriate NEPA review, either remove all known depleted UF_6 cylinders from K-25 or complete the conversion of their contents by December 31, 2009.

In July 1998, the President signed Public Law 105-204 which provides, in part, the following (see Appendix N for the complete text of Public Law 105-204):

> *(a) PLAN. – The Secretary of Energy shall prepare, and the President shall include in the budget request for fiscal year 2000, a Plan and proposed legislation to ensure that all amounts accrued on the books of the United States Enrichment Corporation for the disposition of depleted uranium hexafluoride will be used to commence construction of, not later than January 31, 2004, and to operate, an onsite facility at each of the gaseous diffusion plants at Paducah, Kentucky, and Portsmouth, Ohio, to treat and recycle depleted uranium hexafluoride consistent with the National Environmental Policy Act.*

DOE provided its initial plan for the conversion of depleted UF_6, responsive to Public Law 105-204, to Congress on March 12, 1999. In addition, it issued a Request for Expressions of Interest for a Depleted Uranium Hexafluoride Integrated Solution Conversion Contract and Near-Term Demonstrations on March 4, 1999 (U.S. Department of Commerce 1999). Responses to this request will provide DOE with information to develop a detailed procurement strategy for an integrated approach to the management of DOE's depleted UF_6 inventory. A final plan, incorporating information from the private sector and other stakeholders, is expected to be issued later in 1999.

At this time, DOE has not recommended to the President that any additional legislation be proposed. Any proposal to proceed with the location, construction, and operation of a facility or facilities will involve additional review under NEPA.

1.2 PURPOSE AND NEED

The purpose of this PEIS is to reexamine DOE's management strategy for depleted UF_6 and alternatives to that strategy; DOE needs to take action in response to current economic, environmental, and legal developments. This PEIS examines the environmental consequences of alternative strategies of long-term storage, use, and disposal of the depleted UF_6 inventory. A long-term management strategy will be selected in the Record of Decision, which is scheduled to be issued no sooner than 30 days after the issuance of this PEIS.

1.3 PROPOSED ACTION

The proposed action assessed in this PEIS is DOE's selection of a long-term management strategy for depleted UF_6 that will be implemented following the Record of Decision. A strategy is a set of activities or steps for managing depleted UF_6, from its current storage at the three DOE storage sites to ultimate use, long-term storage, or disposal. The alternative strategies considered in the PEIS evaluate options for continued storage of cylinders, conversion of the UF_6 to other chemical forms, use of the uranium as a metal or an oxide, long-term storage, disposal, and/or transportation. The time period for which activities were assessed for all strategies was approximately 40 years: generally 10 years for siting, design, and construction of any required new facilities; about 26 years for operations; and, when appropriate, about 4 years for monitoring.[3] In addition, for the continued storage component of all alternatives and for the disposal alternative, long-term impacts (primarily from potential groundwater contamination) were estimated. The actual implementation schedule would depend on the ultimate strategy selected in the Record of Decision and on other considerations, and activities could continue beyond the 40-year period. DOE will conduct additional NEPA reviews for such activities as appropriate. The alternative management strategies assessed in this PEIS are described and compared in Chapter 2.

The PEIS provides a broad environmental analysis of the various programmatic management strategies available to DOE. DOE identified a preferred management strategy in the draft PEIS and modified the strategy in this final PEIS (see Section 2.5) on the basis of public comments received on the draft PEIS.

1.4 DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

The Office of Nuclear Energy, Science and Technology within DOE is responsible for the management of the depleted UF_6 generated by enrichment activities and currently stored at the Paducah, Portsmouth, and K-25 sites. To accomplish long-term management, a Depleted Uranium Hexafluoride Management Program was established that includes two sequential phases: (1) selection

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[3] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

of a strategy for long-term management of depleted UF_6 followed by (2) implementation of the strategy selected, including selection of specific technologies, locations, facilities, and processes that may be required. The first program phase, strategy selection, is currently proposed and is the subject of this PEIS. A Record of Decision for this PEIS is expected to be published in the *Federal Register* (FR) no sooner than 30 days after the issuance of this PEIS. The Record of Decision for Phase I will be based on the results of this PEIS, as well as other information, including the information presented in a cost analysis report and an engineering analysis report (Figure 1.5). The Record of Decision will document the management strategy selected and will describe how it was selected from among several alternatives. One consideration in selecting a strategy is the assessment of potential environmental impacts associated with the alternatives.

A Two-Phased Approach: Two Levels of Decision Making

The Depleted Uranium Hexafluoride Management Program is pursuing a two-phased approach to long-term management of depleted uranium hexafluoride (UF_6).

Phase I is the subject of this PEIS and concerns the selection of a long-term management strategy. A strategy is a general approach to managing depleted UF_6, such as long-term storage, use, or disposal of some or all of the material. The strategy selected in Phase I will be announced in a Record of Decision to be issued no sooner than 30 days after the issuance of this PEIS. The selected strategy will identify major management activities required for ultimate disposition of depleted UF_6. Specific sites or technologies to be used would be identified in the next phase.

Phase II will begin following the Record of Decision and will involve the evaluation and selection of specific sites and technologies necessary to implement the strategy selected in Phase I. Phase II will include appropriate NEPA reviews for site and technology selection activities.

To support the evaluation of alternative management strategies for Phase I, DOE conducted engineering analyses to identify the technical characteristics associated with various potential management alternatives. The engineering analyses resulted in the preparation of two reports: the technology assessment report, *Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride*, which was released on June 30, 1995 (Lawrence Livermore National Laboratory [LLNL] 1995); and the engineering analysis report, *Depleted Uranium Hexafluoride Management Program; Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride* (LLNL 1997a), which was released in May 1997.

Prior to preparing these two reports, DOE issued a Request for Recommendations (59 FR 56324) on November 10, 1994, soliciting suggestions for potential uses of depleted UF_6 and for any technologies that could facilitate the long-term management of depleted UF_6. The responses were evaluated by independent technical reviewers and documented in the technology assessment report. The technology assessment report evaluates the potential feasibility of uses for the depleted UF_6 and of technologies for converting the material to other chemical forms, and provides a consolidation of the reviewers' evaluations of all recommendations received. These evaluations, along with other considerations, were used to develop representative technology options considered in this PEIS.

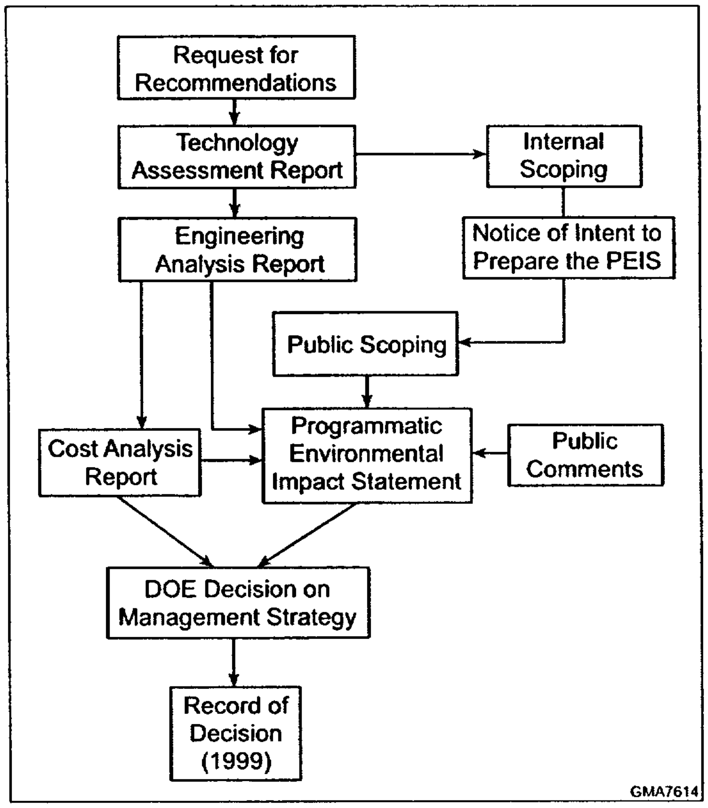

FIGURE 1.5 First Phase of the Depleted Uranium Hexafluoride Management Program

The engineering analysis report (LLNL 1997a) provides a more detailed, in-depth technical analysis of representative management options identified in the technology assessment report. It provides design and operational data for several different types of activities, including options for the preparation of UF_6 cylinders for shipment, conversion of UF_6 to other chemical forms, long-term storage of uranium material, manufacture and use of products containing uranium, and disposal. The engineering analysis report is the primary source of technical data and information for the alternatives evaluated in this PEIS and is incorporated by reference. The engineering analysis report includes descriptions of facility layouts, resource requirements, and construction requirements; estimates of effluents, wastes, and emissions during operations; and descriptions and estimated frequencies for a range of potential accident scenarios. These facility design data, as well as environmental setting information, were used as input to the calculational models or "tools" for estimating potential environmental impacts that could result under each alternative. LLNL's summary of the engineering analysis report is included in its entirety in Appendix O.

DOE also initiated a separate study of the costs of various technology options. The engineering analysis, including the technology assessment report and engineering analysis report, serves as the basis for the cost analysis, which provides estimates of the life-cycle costs associated with long-term management strategies for depleted UF_6. The cost analysis report (LLNL 1997b) was released in May 1997.

Following publication of its Record of Decision, DOE plans to begin a process for selecting sites and technologies necessary to implement the selected strategy. This latter activity is referred to throughout this PEIS as the "second tier," or "Phase II," of DOE decisions regarding depleted UF_6 management. The second tier will include the appropriate NEPA analyses and reviews needed for decisions on site selection, selection of specific technologies for management activities, type and design of facilities, and vendors' industrial processes, as required by the selected alternative.

1.5 SCOPE OF THIS PEIS

Scope refers to the range of actions, alternatives, and impacts to be considered in an EIS. An agency generally determines scope through a two-part process: internal scoping and public scoping. Internal scoping refers to efforts within the agency to identify potential alternatives, identify important issues, and determine the analyses to be included in an EIS. Public scoping refers to the request for public comments on the proposed action and on the results of internal scoping. Public scoping includes consultation with federal, state, and local agencies as well as requests for comments from stakeholder organizations and members of the general public.

On the basis of input received during the public scoping process, the federal agency responsible for the proposed action (DOE) prepares a draft EIS and makes it available to the public for their review and comment. The "public" is broadly defined and includes any and all interested or affected parties, including interested or affected private citizens; state, local, and tribal governments; environmental groups; and civic and community organizations. The responsible agency evaluates the comments received and revises the EIS before issuing it as a final document. The public scoping process for this PEIS is summarized in Section 1.5.1.1. The public review of the draft PEIS and major changes made to the draft before the issuance of the final PEIS are outlined in Section 1.5.1.2.

1.5.1 Public Participation

1.5.1.1 Summary of Public Scoping for the Draft PEIS

DOE published a Notice of Intent to prepare this PEIS, entitled *Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride*, on January 25, 1996 (61 FR 2239), beginning a 60-day scoping period. The Notice contained DOE's preliminary results of internal scoping, including a description of the proposed action, alternatives, and approach to EIS preparation. In addition to providing information on the PEIS, the Notice of Intent invited public participation in determining the scope of the PEIS. Comments were requested by correspondence and by participation in one or more public scoping meetings.

Three PEIS public scoping meetings were held between February 13 and February 20, 1996 — one near each depleted UF_6 storage site. A total of 300 persons attended the meetings, and 169 comments were received. DOE also provided several alternative means for public involvement. A fact sheet titled "Overview of the Programmatic Environmental Impact Statement" was mailed to more than 3,800 individuals and organizations identified by the three current storage sites and through the DOE stakeholder mailing list as parties potentially interested in the PEIS. The fact sheet requested comments and gave directions on how comments should be sent to DOE. In addition, a World Wide Web site was developed, which included an overview of the project, fact sheets, links to other useful Internet sites (e.g., DOE's NEPA Internet site), and directions on how to comment.

The public scoping process generated a total of 235 comments on the proposed scope of the PEIS. These comments were examined to finalize the proposed scope of the PEIS. Comments were related primarily to nine major issues: (1) general environmental concerns, (2) current management, (3) storage, (4) conversion, (5) use, (6) cost, (7) disposal, (8) transportation, and (9) policy issues. Appendix L of this PEIS provides a summary of these comments and a discussion of the comments' effects on the scope of the PEIS, including where scope was changed and where change in scope was inappropriate.

1.5.1.2 Public Review of the Draft PEIS

The draft PEIS was mailed to stakeholders in mid-December 1997, and a notice of availability was published by the U.S. Environmental Protection Agency (EPA) in the *Federal Register* on December 24, 1997. In addition, the entire PEIS was also made available on the World Wide Web at the same time. Stakeholders were encouraged to provide comments on the draft PEIS during a 120-day review period, from December 24, 1997, until April 23, 1998. Comments could be submitted by a toll-free number, by fax, by letter, by e-mail, or through the World Wide Web site. Comments could also be submitted at four public hearings held during a period from February 19, 1998, to March 10, 1998. Public hearings were held near each of the three current storage sites (Paducah, Kentucky; Oak Ridge, Tennessee; and Portsmouth, Ohio) and another in Washington, D.C.

A total of about 600 comments were received during the comment period. The comments received and DOE's responses to those comments are presented in Volume 3 of this PEIS. Several revisions were made to the draft PEIS on the basis of the comments received. A summary of the major issues raised by the reviewers of the draft PEIS and DOE's resolution of these issues are as follows:

- *Comments related to the preferred alternative.* Many of the reviewers questioned DOE's preference for beginning to convert the depleted UF_6 inventory to uranium oxide or uranium metal only as uses for these materials became available. Several reviewers expressed a desire for DOE to start conversion as soon as possible. Conversion to U_3O_8 was the option most often cited as preferred, although several reviewers thought conversion to metal would be more advantageous. In addition, many reviewers expressed doubt about the prospects for any widespread uses for depleted uranium now or in the future.

After careful consideration of comments, DOE revised the preferred alternative for the final PEIS. The preferred alternative, as stated in Section 2.5 of this final PEIS, calls for prompt conversion of the depleted UF_6 inventory to U_3O_8 and long-term storage of that portion of the U_3O_8 that cannot be put to immediate use. Under this revised preferred alternative, conversion to depleted uranium metal would take place only if uses for the metal products become available. The impacts of the preferred alternative are discussed in Sections 2.5.2, 5.7, and 6.3.7 of the PEIS.

- *Comments related to seismic hazards at the Paducah site.* Several reviewers commented that the draft PEIS did not adequately address the seismic hazards at the Paducah site. They requested that DOE review new information that came to light very recently and reevaluate the risks associated with potential earthquakes at Paducah.

  In response, DOE reviewed those references that were available at the time this final PEIS was prepared. DOE determined that the analyses performed as part of the safety analysis reports recently completed at the three current storage sites (including Paducah) and for this PEIS were adequate. However, one reference identified in a comment from the State of Kentucky was not available in time to be considered in the preparation of the final PEIS. DOE will review that reference and any other data when they become available and take appropriate action to maintain the safety basis of its cylinder management program. In addition, if new facilities are to be constructed at Paducah or any other site, the latest information concerning seismic hazards at that site would be factored into the design of the new facilities.

- *Comments related to potential life-cycle impacts.* Several reviewers stated that depleted uranium and products made from using depleted uranium in various chemical forms would eventually need to be disposed of. They requested that the PEIS include a discussion of impacts for the disposal of these materials following long-term storage and use. The draft PEIS had included a discussion of potential impacts from management activities through the year 2039 for all alternatives and evaluation of long-term impacts (primarily from groundwater contamination) from the continued storage component of all alternatives and for the disposal alternative.

  In response to commentors' requests for life-cycle impact analysis, a new section was added to this PEIS (Section 5.9) to discuss issues related to the potential impacts of the long-term (beyond 2039) management of materials containing depleted uranium under all alternatives. However, because of the uncertainties associated with the events that would occur far into the future and with the regulatory atmosphere at that time, the discussion is limited to issues that would need to be considered and the options that would be available for managing the material beyond 2039.

- *Comments related to the cylinder inventory.* Several reviewers questioned the accuracy of the reported number of DOE-owned cylinders of depleted UF_6 (46,422) considered in the draft PEIS. Other reviewers requested that USEC-generated cylinders also be included within the scope of the PEIS.

  Upon review, confusion related to the size of the DOE cylinder inventory appears to have resulted because the numbers published in various DOE reports sometimes included only the full cylinders of depleted UF_6 and other times included not only the full cylinders but also heel cylinders and cylinders containing natural UF_6. Although the number 46,422 that is used in the draft PEIS was accurate at the time the document was published, subsequent privatization of USEC and transfer of some cylinders from USEC to DOE changed the inventory of depleted UF_6 that falls within the scope of the PEIS (see Section 1.5.2). Chapter 6 has been added to the PEIS and Chapter 2 and the Summary have been revised so the PEIS includes the impacts associated with the management of additional USEC-generated cylinders. The heels cylinders are also included in the scope of the PEIS (see Section 1.5.2).

- *Comments related to current cyclinder management.* Several reviewers raised questions and concerns about the current management of the cylinders at the three DOE locations.

  In response to these concerns, it has been emphasized that DOE's current cylinder management program provides for safe storage of the depleted UF_6 cylinders. DOE is committed to the safe storage of the cylinders at each site during the decision-making period and also through the implementation of the decision made in the Record of Decision. DOE has an active cylinder management program that involves upgrading cylinder storage yards, constructing new yards, repainting cylinders to arrest corrosion, and regular inspection and surveillance of the cylinders and storage yard conditions.

The changes made in response to public comments, including the inclusion of up to 15,000 USEC cylinders, did not affect the types or overall significance of the environmental impacts presented in the draft PEIS. Although the estimated impacts did increase by up to 30% in some assessment areas, this increase was generally not significant because the impacts were typically small to begin with. Many impacts did not change at all as a result of including the USEC cylinders because these impacts were related to factors that were unaffected by the inventory increase. For example, the consequences of potential accidents did not increase, because accidents generally involve only a limited amount of material that would be available, regardless of the overall inventory. In addition, other impacts did not change because they were related to the annual material processing rates, which were assumed to remain the same when the USEC cylinders were included. Consequently, it was not necessary to recirculate the draft PEIS for additional public review. The nature and magnitude of changes in environmental impacts resulting from the addition of USEC cylinders are discussed in Sections 2.4, 2.5, and Chapter 6 of this PEIS.

1.5.2 Cylinder Inventory

This PEIS considers the depleted UF_6 inventory stored at the Paducah site, Portsmouth site, and K-25 site on the Oak Ridge Reservation for which DOE has management responsibility. This inventory includes depleted UF_6 generated by DOE before the formation of USEC in July 1993 as well as depleted UF_6 generated by USEC that has been or will be transferred to DOE. Specifically, the PEIS considers the management of 46,422 cylinders generated by DOE and up to 15,000 cylinders generated by USEC.

The depleted UF_6 inventory generated by DOE before July 1993 consists of 46,422 cylinders that contain approximately 560,000 metric tons of UF_6; of these, 28,351 cylinders are located at Paducah (342,000 metric tons), 13,388 are at Portsmouth (161,000 metric tons), and 4,683 are at K-25 (56,000 metric tons).

In addition to the DOE cylinder inventory, management responsibility for approximately 11,400 depleted UF_6 cylinders (about 137,000 metric tons) was transferred from USEC to DOE by the signing of two MOAs. The MOA between DOE and USEC related to depleted uranium generated before the privatization date was signed in May 1998 (DOE and USEC 1998a). It transferred management responsibility for approximately 9,400 cylinders (about 6,600 cylinders stored at Paducah and about 2,800 stored at Portsmouth) from USEC to DOE. A second MOA between DOE and USEC related to depleted uranium, signed in June 1998, transfers approximately 2,000 depleted UF_6 cylinders from USEC to DOE between 1999 and 2004 (DOE and USEC 1998b). (The locations of these cylinders are not specified in this second agreement.)

To account for uncertainties related to the management of depleted UF_6 generated by USEC in the future, the analysis in the PEIS considers management of up to 15,000 USEC-generated cylinders (approximately 180,000 metric tons). For the purposes of analysis, it was assumed that 12,000 of the USEC-generated cylinders would be managed at Paducah and 3,000 would be managed at Portsmouth.

Also included in the scope of this PEIS is a total of approximately 200 cylinders at the three sites that contain small amounts of material. These cylinders, which are termed "heels" cylinders, contain a total of about 2,300 lb of depleted UF_6, less than 0.0002% of the inventory. A cylinder heel is defined as the residual amount of nonvolatile material remaining in a cylinder after removal of the depleted UF_6. For this PEIS, it has been assumed that the heels cylinders will continue to be safely stored under the cylinder management program. If a management strategy that involves conversion is selected, these existing heels cylinders will be treated in the same way as the heels cylinders that would be generated from the conversion process. Details on the treatment of heels cylinders are given in Appendix F, Section F.2.

1.5.3 Alternative Management Strategies and Types of Activities

The alternatives that are evaluated and compared in this PEIS represent the consensus of both DOE and the general public regarding reasonable strategies for the long-term management of depleted UF_6. The alternative management strategies were developed and announced in the Notice of Intent to prepare this PEIS. The following alternatives are assessed in the PEIS: the no action alternative, which considers continuation of current cylinder storage and management practices indefinitely; two long-term storage alternatives; two use alternatives; and one disposal alternative. These alternatives, as well as DOE's preferred alternative, are described in detail in Chapter 2.

In addition to the management strategies considered in this PEIS, the use of some depleted UF_6 is being considered pursuant to other DOE programs, such as the disposition of surplus plutonium. Uses being considered by other DOE programs, which are subject to future decisions and other NEPA reviews, would generally involve only a small fraction of the depleted UF_6 inventory currently in storage and would not affect the selection of a long-term management strategy.

At the time of public scoping, the no action alternative was based on the course of action outlined by Sewell (1992) (Section 1.1). This course of action included chemical conversion of depleted UF_6 to the oxide U_3O_8, beginning in the year 2020 and continuing for 20 years, followed by storage of the U_3O_8. After public scoping and based on internal DOE reviews, the no action alternative was modified to be the continued storage of UF_6 cylinders indefinitely at the three current storage sites.

Each alternative consists of several management activities. The types of management activities included in the alternatives have been grouped into seven major categories, as shown in Figure 1.6. Within each category, several representative options, consisting of either design or technology variations, were considered. It is important to note that the options are representative in nature and were selected to provide a basis for comparing broad, programmatic management strategies. These seven categories of activities formed the main building blocks for evaluating all of the alternatives in the PEIS — each alternative strategy is composed of a combination, or series, of several of these management activities. The following categories of activities were included:

- ***Continued Cylinder Storage:*** Depleted UF_6 cylinders would continue to be stored in yards at the three current storage sites for some period of time for all alternatives. During that time, current cylinder management practices would continue to ensure that cylinders were maintained in a safe condition.

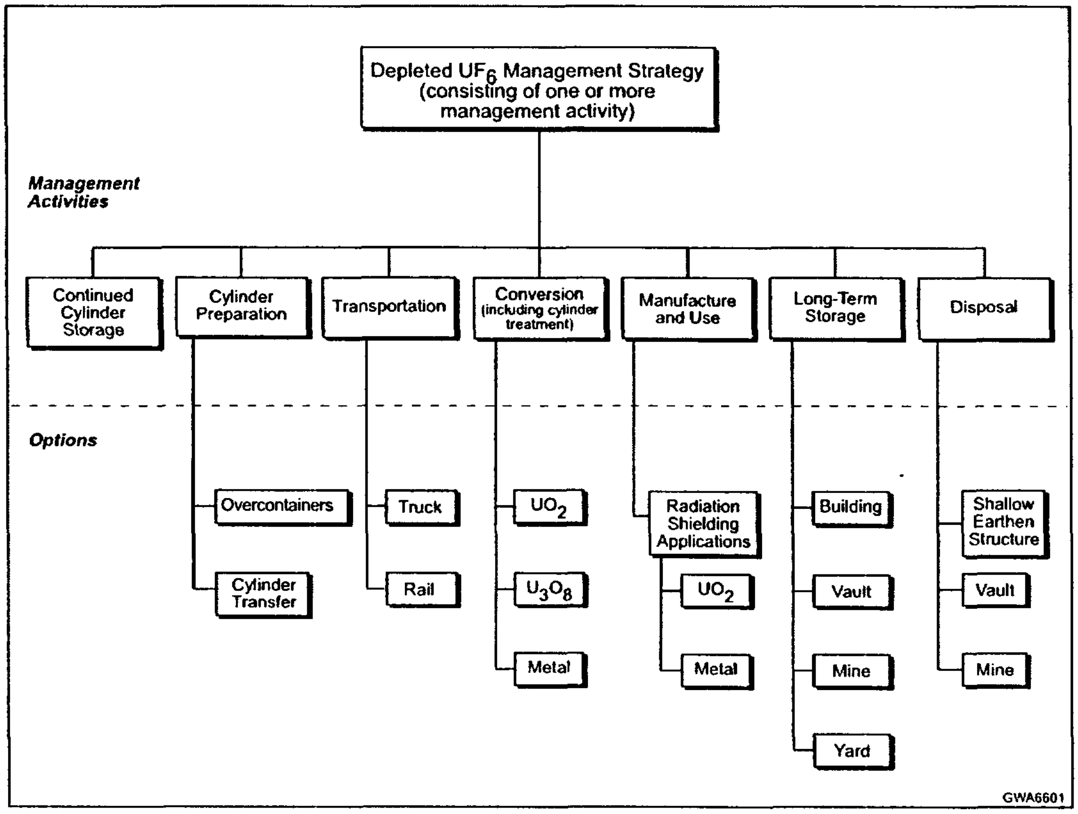

FIGURE 1.6 Options for Depleted UF_6 Management Activities (All alternative strategies consist of some combination of these activities.)

- ***Cylinder Preparation Options:*** If depleted UF_6 cylinders were to be shipped from the current storage sites, some cylinders might require preparation to make them suitable for transportation. Two options were considered for these activities: (1) use of overcontainers, which are large metal containers certified to meet U.S. Department of Transportation (DOT) shipping requirements, into which cylinders could be placed, and (2) use of a cylinder transfer facility, which could be used to transfer the UF_6 contents from old cylinders to new cylinders.

- ***Transportation Options:*** It is possible that the cylinders might have to be transported from the current storage sites, depending on the ultimate locations selected for conducting future management activities. Therefore, the transport of cylinders by both truck and rail was evaluated. Also considered was the transport of all other materials that might be required for or produced by the different alternative strategies.

- ***Conversion Options:*** Some alternatives would involve the conversion of depleted UF_6 into another chemical form prior to long-term storage, use, or disposal. The different chemical forms of uranium considered include two uranium oxides — U_3O_8 and uranium dioxide (UO_2) — and uranium metal. The treatment of emptied cylinders is also considered.

- ***Manufacture and Use Options:*** Depleted UF_6 could potentially be used to manufacture products with beneficial applications. The analysis in this PEIS considered, as a representative application, the use of a converted form of depleted UF_6 to manufacture a dense material to be used for shielding against gamma radiation. The selection of shielding as a representative use option is not intended to imply that the PEIS will be used to select a specific end-use or will preclude other uses.

- ***Long-Term Storage Options:*** Depleted UF_6 cylinders or uranium oxide (following conversion) could be placed into long-term storage. Four different long-term storage options were considered: buildings, belowground vaults, mines, and yards.

- ***Disposal Options:*** Depleted UF_6 could be disposed of as LLW following conversion to an oxide form. Three disposal facility options were considered: shallow earthen structures, belowground vaults, and mines.

Impacts resulting from the decontamination and decommissioning of any required facilities are expected to be relatively small when compared with the impacts resulting from the construction and operation of these facilities. Inclusion of the decontamination and decommissioning impacts would not affect the comparison of the programmatic alternatives analyzed and the conclusions reached in this PEIS. The decontamination and decommissioning impacts would be considered in the follow-on site-specific and facility-specific environmental planning and analysis documents.

1.5.4 Environmental Setting Considerations

Because this PEIS is an analysis of programmatic strategies, rather than specific siting alternatives, certain impacts have been assessed using representative or generic environmental settings. In particular, impacts associated with potential conversion, long-term storage, manufacturing, transportation, and disposal activities were assessed assuming representative or generic site environmental conditions. The purpose of this approach was to provide as substantive an assessment as possible and to allow for a comprehensive comparison of alternative management strategies. The activities that would normally take place at the current storage sites (Paducah, Portsmouth, and K-25) were assessed using site-specific data. These activities include continued cylinder storage and cylinder preparation for off-site shipment.

After the Record of Decision, DOE would evaluate potential facility locations and whether the facilities would be owned or operated by the private sector or the federal government. Depending on the strategy selected, DOE would evaluate a range of reasonable alternatives to select the sites for potential conversion, long-term storage, manufacturing, and disposal facilities. These subsequent analyses would be performed using site-specific environmental data.

Site selection activities would include an evaluation of site characteristics, such as the site's potential response to seismic events, potential for flooding, and geology, to ensure that suitable locations were chosen. Following site selection, any new facilities would be designed and built to meet engineering and construction standards and requirements appropriate for the selected location and the mission of the facility.

Environmental Settings Used in the PEIS Analysis

Existing site environmental settings were used for analysis of continued cylinder storage activities for all alternatives. Site-specific data were also used for analysis of cylinder preparation activities for off-site shipment of cylinders. The depleted UF_6 cylinders are currently located at the Paducah site, Portsmouth site, and K-25 on the Oak Ridge Reservation.

Generic environmental settings were used for analysis of manufacturing, disposal, and long-term storage in mines. These settings were selected on the basis of generalized environmental characteristics — such as a wet (or eastern United States) location and a dry (or western United States) location.

Representative environmental settings were used for analysis of conversion and long-term storage in yards, buildings, and vaults. These settings were selected on the basis of conditions at sites that, although not proposed for that activity, might be somewhat similar to an eventual site. In this PEIS, the conditions at the current storage sites were used to define a range of representative environmental settings. For the transportation analysis, representative route characteristics were based on national-average data.

1.5.5 Human Health and Environmental Issues

This PEIS evaluates and compares the potential impacts on human health and the environment for the alternative management strategies considered. In general, the PEIS emphasizes those impacts that may differentiate among alternatives or are of special interest to the general public (such as potential radiation effects). The assessment of potential environmental impacts is based primarily on the preliminary engineering data included in the engineering analysis report (LLNL 1997a). That report contains data on cylinder preparation and transportation, conversion, manufacturing, long-term storage, and disposal. The report includes descriptions of facility layouts; discussion of resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios for the depleted UF_6 management options considered in this PEIS (see Appendix O for a summary of the engineering analysis report).

The PEIS includes the assessment of impacts to human health and safety, air, water, soil, biota, socioeconomics, cultural and archeological sites, site waste management capabilities, resource requirements, and environmental justice. Issues judged by DOE to be of greatest concern or public interest, and receiving more detailed analysis, include impacts to human health and safety, air and water, waste management capabilities, and socioeconomics. These issues are consequently treated in greater detail in the PEIS.

The environmental impacts for each alternative were determined by combining, as appropriate, the potential impacts associated with each of the individual activities that would be required to implement the alternative. The level of analysis conducted depended on the specific activity considered. The potential impacts during continued cylinder storage and cylinder preparation for shipment activities were evaluated for the environmental settings at the three current storage sites; potential impacts of conversion, manufacture and use, long-term storage, transportation, and disposal activities were evaluated for representative or generic environmental settings (see Chapter 3 for descriptions of the affected environments of these settings). The intent of the analysis at representative or generic environmental settings was to estimate a reasonable range of potential impacts to allow for a meaningful comparison of alternative strategies. Subsequent analysis with site-specific environmental data will be performed during the Phase II studies and NEPA reviews.

Estimating environmental impacts for alternative approaches to depleted UF_6 management is subject to uncertainty, primarily as a consequence of the (1) preconceptual nature of facility designs, (2) unknown location of future facilities, and (3) characteristics of the methods used to estimate impacts. This impact assessment was designed to ensure — through selection of assumptions, models, and input parameters — that impacts would not be underestimated and that relative comparisons among the alternatives would be valid and meaningful. This approach was developed by uniformly applying common assumptions to each alternative and by choosing assumptions intended to produce conservative estimates of impacts — that is, assumptions that would lead to overestimates of the expected impacts. Although uncertainty may characterize estimates of the absolute magnitude of impacts, a uniform approach to impact assessment enhances the ability to make valid comparisons among alternatives. This uniform approach was implemented in the analyses conducted for the PEIS to the extent practicable.

1.6 RELATIONSHIP TO OTHER NEPA REVIEWS

DOE has prepared, or is in the process of preparing, other NEPA reviews that are related to the management of depleted UF_6 or to the three current depleted UF_6 storage sites. These NEPA reviews are as follows:

- *Disposition of Surplus Highly Enriched Uranium, Final Environmental Impact Statement* (DOE 1996a): This EIS addresses the disposition of a nominal 200 metric tons of highly enriched uranium declared surplus to the national security needs of the United States. Alternatives include several approaches for blending down the highly enriched material to make it nonweapons-usable and suitable for fabrication into fuel for use in commercial nuclear reactors. Commercial use alternatives included transferring up to

50 metric tons of highly enriched uranium to USEC facilities for blending with natural uranium. The draft EIS was issued in October 1995 and the final EIS in June 1996. The Record of Decision (August 5, 1996) calls for blending, over time, as much material as possible (up to 85%) for commercial use, and blending the remainder for disposal as low-level waste. This EIS is related to the Depleted UF_6 PEIS in that USEC facilities are located at two of the current storage sites for depleted UF_6, Paducah and Portsmouth. The cumulative impacts analysis in the Depleted UF_6 PEIS takes into account the results of this EIS on disposition of highly enriched uranium.

- *Proposed Sale of Radioactively Contaminated Nickel Ingots Located at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Environmental Assessment* (DOE 1995b): This environmental assessment evaluates the impacts of the sale of radioactively contaminated materials, primarily nickel, that have potential value as a resource. These materials are stored at the Paducah Gaseous Diffusion Plant on the Paducah site. The final environmental assessment and Finding of No Significant Impact were issued in October 1995. This environmental assessment is related to the Depleted UF_6 PEIS because Paducah is currently a storage site for depleted UF_6. The cumulative impacts analysis in the Depleted UF_6 PEIS takes into account the results of this environmental assessment.

- *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE 1995a): This EIS comprises a complexwide evaluation of reasonable alternatives for managing existing and reasonably foreseeable amounts of spent nuclear fuel within the DOE inventory through the year 2035. This inventory includes the spent nuclear fuel currently stored at Oak Ridge National Laboratory on the Oak Ridge Reservation. This EIS contains an analysis of the transportation of spent nuclear fuel. That analysis has been referenced where relevant to the transportation analysis for the Depleted UF_6 PEIS. It is also related to the Depleted UF_6 PEIS because if a use alternative were selected, uranium-shielded casks could be used to store spent nuclear fuel. The final EIS was issued in April 1995, and a Record of Decision selecting three regionalized DOE locations for management of spent nuclear fuel (Hanford, Idaho National Engineering Laboratory, and the Savannah River Site) was issued in June 1995.

- *Refurbishment of Uranium Hexafluoride Cylinder Storage Yards C-745-K, L, M, N, and P and Construction of a New Uranium Hexafluoride Cylinder Storage Yard (C-745-T) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Environmental Assessment* (DOE 1996e): This environmental assessment addresses improvements to depleted UF_6 cylinder storage conditions at the Paducah site. It includes both refurbishment of existing storage yards and construction of a new storage yard. A Finding of No Significant Impact has been issued for these activities. In the Depleted UF_6 PEIS, the upgrades planned to occur prior to 1999 are considered to be part of the affected environment for the Paducah site.

- *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management* (DOE 1996c): This EIS evaluates the potential environmental impacts resulting from activities associated with nuclear weapons research, design, development, and testing, as well as assessing and certifying their safety and reliability. The stewardship portion of the document analyzes the development of three new facilities to provide enhanced experimental capability. The stockpile management portion of this EIS concerns producing, maintaining, monitoring, refurbishing, and dismantling the nuclear weapons stockpile at eight possible sites, including the Oak Ridge Reservation. The final PEIS was released in November 1996, and the Record of Decision was issued on December 26, 1996 (61 FR 68014). A decision was made to downsize certain facilities at the Y-12 Plant on the Oak Ridge Reservation. This EIS is related to the Depleted UF_6 PEIS only because the K-25 site is part of the Oak Ridge Reservation. The cumulative impacts analysis in the Depleted UF_6 PEIS takes into account the results of this EIS on stockpile stewardship.

- *Storage and Disposition of Weapons-Usable Fissile Materials, Final Programmatic Environmental Impact Statement* (DOE 1996d): This EIS evaluates the environmental impacts of alternative approaches for the long-term storage and disposition of weapons-usable fissile materials — that is, highly enriched uranium and weapons-usable plutonium. Alternatives for long-term storage included the no action alternative, upgrade at multiple sites, consolidation of plutonium at one site, and colocation of plutonium or highly enriched uranium at one site. In a Record of Decision issued in January 1997, DOE decided, in part, to store highly enriched uranium in upgraded and consolidated facilities at the Y-12 Plant on the Oak Ridge Reservation. This EIS relates to the Depleted UF_6 PEIS because the K-25 site is also located on the Oak Ridge Reservation. The cumulative impacts analysis in the Depleted UF_6 PEIS takes into account the results of this EIS on storage and disposition of weapons-usable fissile materials.

- *Environmental Assessment for the DOE Sale of Surplus Natural and Low Enriched Uranium* (DOE 1996b): This environmental assessment reviews DOE's proposed action for the sale of about 35.7 million lb (16.2 million kg) U_3O_8 of uranium for subsequent enrichment and fabrication into commercial nuclear reactor fuel. The uranium is currently in the forms of natural and low-enriched UF_6, which is stored at the Paducah and Portsmouth sites (the material considered in this environmental assessment is different than the depleted UF_6 considered in the Depleted UF_6 PEIS). The natural and low enriched UF_6 would be sold to various entities, which could include USEC, currently the only domestic provider of uranium enrichment services; over 60 electric utilities in the United States and abroad; converters; traders; and uranium producers. This environmental assessment is related to the PEIS because of potential cumulative impacts at the Paducah and Portsmouth sites, which are also current depleted UF_6 storage sites. The cumulative impacts analysis of the Depleted UF_6 PEIS takes into account the results of this environmental assessment.

- *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DOE 1997a): This EIS (referred to herein as WM PEIS) evaluates the impacts of different approaches to the treatment, storage, and disposal of the existing and projected DOE inventory of certain types of waste management programs wastes over the next 20 years. The WM PEIS considers radioactive low-level, high-level, transuranic, and mixed wastes, as well as toxic and hazardous wastes. The amounts of wastes analyzed for treatment, storage, or disposal range from thousands to millions of cubic meters and include wastes generated at the DOE sites in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. The WM PEIS does not evaluate management of depleted UF_6 because that material is considered a source material, not a waste. The draft PEIS was issued in September 1995 and the final PEIS in May 1997.

  The WM PEIS considers the impacts of waste management at Paducah, Portsmouth, and the Oak Ridge Reservation based on the existing and projected inventories of waste generated during site operations. The three sites are also considered as candidate sites for regionalized waste management sites, and waste management impacts are evaluated for these scenarios as well. Cumulative impacts of current operations, waste management, and proposed future operations are also assessed for the three sites in the WM PEIS. Both the waste management analysis and cumulative impacts analysis in the Depleted UF_6 PEIS take into account the results of the WM PEIS.

- *Surplus Plutonium Disposition Draft Environmental Impact Statement* (DOE 1998a). This EIS examines reasonable alternatives and potential environmental impacts for the proposed siting, construction, and operation of three types of facilities for plutonium disposition. One of the facilities would fabricate plutonium oxide and depleted uranium oxide into mixed oxide fuel. The mixed oxide fuel fabrication facility would be located at either Hanford, Idaho National Engineering and Environmental Laboratory, Pantex, or the Savannah River Site.

This EIS analyzes the use of approximately 1,000 tons of existing DOE stocks of depleted UF_6. The depleted UF_6 would be shipped from current locations to a commercial facility for conversion to uranium oxide. This material would then be shipped to the mixed oxide fuel fabrication plant. Mixed oxide fuel would be used in existing commercial light water reactors in the United States, with subsequent disposal of the spent fuel in accordance with the *Nuclear Waste Policy Act*. This EIS is related to the PEIS in that it could possibly use a small portion of the depleted UF_6 inventory.

- *Final Environmental Assessment for the Lease of Land and Facilities within the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE 1997b). This environmental assessment was issued in November 1997 and evaluates the potential environmental impacts of leasing land and facilities at the K-25 site in Oak Ridge, Tennessee. The leasing program examined represents a reindustrialization effort by DOE, making vacant, underutilized, and/or inactive facilities available to private sector firms or other organizations for industrial, commercial, office, research and development, and manufacturing uses. In addition to increasing the use of DOE-owned resources, the program assessed in this document would reduce costs to DOE by lessening surveillance and maintenance requirements and, in some cases, by having lessees decontaminate facilities on the site. This environmental assessment is related to the PEIS because of potential cumulative impacts at the K-25 site, currently also a depleted UF_6 storage site. The cumulative impacts analysis of the PEIS takes into account the results of this environmental assessment.

- *Draft Environmental Assessment for the Proposed Treatment of Mixed Wastes at the Paducah Gaseous Diffusion Plant Using the Vortec Vitrification System* (DOE 1998b). This environmental assessment, issued as a draft in March 1998, evaluates the potential environmental impacts of building and operating a facility for the Vortec Cyclone Melting System™ at the Paducah site. This system may treat some portion of the LLW, low-level mixed waste (LLMW), and wastes regulated under the *Toxic Substances Control Act* (TSCA) that are stored at the Paducah Gaseous Diffusion Plant, thereby enabling their removal from storage to disposal. This environmental assessment is related to the PEIS because of potential cumulative impacts at the Paducah site, currently also a depleted UF_6 storage site. The cumulative impacts analysis of the PEIS takes into account the results of this environmental assessment.

1.7 OTHER DOCUMENTS AND STUDIES RELATED TO DEPLETED UF_6 MANAGEMENT

The management of the depleted UF_6 inventory has been independently reviewed by several other agencies and organizations external to the DOE Office of Nuclear Energy, and reports have been released by these groups summarizing their findings. The following is a list of the reports reviewed as a part of the preparation of this PEIS; the results of these reports were included in the PEIS analyses, as appropriate.

- *Defense Nuclear Facilities Safety Board Recommendation 95-1* (DNFSB 1995): In May 1995, the DNFSB issued Recommendation 95-1 regarding the storage of the depleted UF_6 cylinders. This recommendation addressed three items: (1) start of an early program to review the protective coating of cylinders containing the tails (i.e., depleted UF_6) from the historical production of enriched uranium, (2) exploration of the possibility of additional measures to protect these cylinders from the damaging effects of exposure to the elements as well as any additional handling that might be called for, and (3) institution of a study to determine whether a more suitable chemical form should be selected for long-term storage of depleted uranium.

  DOE accepted Recommendation 95-1 in June 1995 and emphasized the following focus areas for its response: removing cylinders from ground contact and keeping cylinders from further ground contact, relocating all cylinders into adequate inspection configurations, repainting cylinders as needed to avoid excessive corrosion, updating handling and inspection procedures and site-specific safety analysis reports (SARs), and completing an ongoing study that would include an analysis of alternative chemical forms for the material. Since 1995, actions have been taken to address each of these focus areas. Several cylinder yards have been reconstructed or newly constructed, and many of the cylinder relocations required to achieve adequate inspection configurations and removal from ground contact have been completed. A cylinder painting program has been initiated; the site-specific SARs have been updated (Lockheed Martin Energy Systems, Inc. [LMES] 1997a,b,c); and a Cylinder Project Management Plan with updated cylinder handling and inspection procedures has been completed (LMES 1997i). In addition, this PEIS, which analyzes alternative management strategies, including various chemical forms of depleted uranium, has been prepared partially in response to the DNFSB recommendation. This PEIS incorporates the information provided in the Cylinder Project Management Plan in its analysis of the impacts of continued cylinder storage and incorporates the results of the SARs in its cylinder accident impact analyses.

The DNFSB reviews DOE's progress in achieving the objectives of Recommendation 95-1 regularly. Additionally, the Board visits the storage sites on a regular basis and has a resident member in Oak Ridge.

- "Disposition of the DUF_6" (National Research Council 1996): A chapter in a book addressing opportunities for cost reduction in the decontamination and decommissioning of the nation's uranium enrichment facilities was devoted to the problems associated with management of the depleted UF_6 inventory. The main conclusion of the report was that if significant new uses had not been identified by 1998, the conversion of the depleted UF_6 inventory to U_3O_8 for long-term storage should begin, and that conversion should start with cylinders in poor condition. The report also concluded that use of a process in which "recyclable" HF would be produced would be the most feasible approach to liquidation of the large inventory. This PEIS addresses questions similar to those examined in the National Research Council report, but it addresses them in the form of alternative management strategies and in the context of the affected environment, as required under NEPA.

- *Depleted Uranium: A DOE Management Challenge* (DOE 1995c): This report examines the technical feasibility and costs of using depleted uranium for shielding in the form of either metal or a concretelike oxide aggregate. It also addresses the alternative recommending disposal of the inventory.

- *The Ultimate Disposition of Depleted Uranium* (Lemmons et al. 1990): This document concludes that it is desirable to maintain working inventories in the form of depleted UF_6 as long as there is a potential for it to be used and as long as cylinders and storage facilities are adequately monitored and maintained. However, at the time the report was written, it appeared that it would be viable to use only a small portion of the inventory, so the report recommended that the majority of the inventory be converted to U_3O_8 for long-term storage or disposal.

In addition to the above documents, the *Final Environmental Impact Statement for the Construction and Operation of Claiborne Enrichment Center, Homer, Louisiana* (U.S. Nuclear Regulatory Commission [NRC] 1994b) was reviewed for its applicability to analyses conducted for this PEIS. The purpose of the NRC document was to assess the impacts of a gaseous centrifuge uranium enrichment facility. Of interest with respect to this PEIS, the NRC document included an analysis of the impacts from a generic facility for converting depleted UF_6 to U_3O_8, and an analysis of the impacts from disposing of the U_3O_8. The findings of the NRC analysis were similar to the findings of the analyses for this PEIS; specifically, that (1) environmental impacts from the construction and operation of a generic uranium conversion facility would be small; (2) external doses from airborne releases would be about one million times less than internal doses; (3) disposal of the U_3O_8 in a near-surface facility in a wet environment could lead to radiological exposure doses that exceed the 25 mrem/yr limit given in DOE Order 5820.2A and 10 CFR Part 61 ("Licensing Requirements for Land Disposal of Radioactive Waste"); and (4) disposal of the U_3O_8 in a generic deep disposal site (such as a mine) would not lead to radiological exposure doses that exceed the 10 CFR Part 61 limit. However, the NRC disposal analyses differed from those in this PEIS with respect to environmental conditions at the sites; the NRC analysis did not differentiate between disposal facilities in wet and dry environmental settings. In this PEIS, analyses were conducted separately for disposal in dry and wet environments. Under the assumptions used in this PEIS, disposal in near-surface and deep disposal facilities in a wet environment was found to lead to radiological doses in excess of 25 mrem/yr; disposal in near-surface and deep disposal facilities in a dry environment did not lead to doses in excess of 25 mrem/yr. Further details on the potential long-term impacts of disposal of uranium oxide are given in Section 5.6 and in Section I.4 of Appendix I.

1.8 ORGANIZATION OF THIS PEIS

The Depleted UF_6 PEIS consists of 11 chapters, 15 appendices, and comments/responses from the public review. Brief summaries of the main components of the PEIS are as follows:

1.8.1 Volume 1 — Main Text

- Chapter 1 introduces the PEIS, discussing pertinent background information, purpose and need for the DOE action, scope of the assessment, related NEPA reviews, other related reports and studies, and EIS organization.

- Chapter 2 defines the alternative management strategies considered in the PEIS and presents a summary comparison of the estimated environmental impacts. The DOE preferred alternative is identified and discussed.

- Chapter 3 discusses the environmental setting at the three DOE facilities currently storing depleted UF_6. Chapter 3 also presents the environmental characteristics of representative and generic environmental settings assumed for the assessment of long-term storage, manufacture and use, conversion, and disposal activities.

- Chapter 4 addresses the assumptions on which the PEIS and its analyses are based, defines the approaches to environmental impact assessment taken in development of the PEIS, and describes the methods of analysis.

- Chapter 5 presents the environmental impacts of the alternatives, including the no action alternative, from managing the inventory of DOE-generated cylinders. This chapter also discusses potential cumulative impacts at the Paducah, Portsmouth, and K-25 sites; issues related to potential life-cycle impacts associated with the alternatives; possible mitigation of adverse impacts that are unavoidable; irreversible commitment of resources; the relationship between short-term use of the environment and long-term productivity; and pollution prevention and waste minimization.

- Chapter 6 presents the environmental impacts associated with the management of up to 15,000 USEC-generated cylinders.

- Chapter 7 identifies the major laws, regulations, and other requirements applicable to implementing any of the alternatives.

- Chapter 8 is an alphabetical listing of all the references cited in the PEIS. All cited references are available to the public.

- Chapter 9 lists the name, education, and experience of persons who helped prepare the PEIS. Also included are the subject areas for which each preparer was responsible.

- Chapter 10 presents brief definitions of the technical terminology used in the PEIS.

- Chapter 11 is a subject-matter index for Volumes 1 and 2 that provides page numbers where important terms and concepts are discussed.

1.8.2 Volume 2 — Appendices

- Appendix A discusses the chemical forms and characteristics of uranium and its compounds.

- Appendix B examines the issues of corrosion of depleted UF_6 cylinders and material loss from breached cylinders, including causes of corrosion and the experience with corrosion at the three current storage sites.

- Appendix C presents a detailed description of the analytical methods used to conduct the impact assessments for the PEIS.

- Appendices D through J address the impacts of options for the activities that make up the alternative management strategies. The impacts are presented for the following:
  - Continued cylinder storage — Appendix D,
  - Preparation of cylinders for shipment — Appendix E,
  - Conversion of UF_6 to an oxide or metal and treatment of heels cylinders and empty cylinders — Appendix F,
  - Long-term storage — Appendix G,
  - Manufacture and use — Appendix H,
  - Disposal — Appendix I, and
  - Transportation — Appendix J.
- Appendix K provides the results of the parametric analysis, which examines the differences in potential environmental impacts if facilities were smaller than full-sized. Appendix K also includes a summary of impacts for several combinations of alternative strategies.
- Appendix L summarizes the comments received during public scoping and discusses how these comments affected the scope of this PEIS.
- Appendix M contains the contractor disclosure statement.
- Appendix N provides the full text of Public Law 105-204.
- Appendix O contains the summary of the engineering analysis report.

1.8.3 Volume 3 — Responses to Public Comments

- Chapter 1 provides an overview of the public participation and comment process.
- Chapter 2 contains copies of the actual letters or other documents that transmitted public comments on the draft PEIS to DOE.

- Chapter 3 lists DOE's responses to written comments received through the mail or electronic media.

- Chapter 4 lists DOE's responses to comments received verbally at the public hearings.

- Chapter 5 consists of two indexes for Volume 3 that provide page numbers where comments and responses are located. One index is organized by commentor name and the other by document number.

3 AFFECTED ENVIRONMENT

Depleted UF_6 is currently managed at three locations: the Paducah site near Paducah, Kentucky; the Portsmouth site near Portsmouth, Ohio; and the K-25 site on the Oak Ridge Reservation near Oak Ridge, Tennessee. In the context of this PEIS, a distinction is made between "site" (the entire DOE facility), a gaseous diffusion plant (a USEC-operated facility within the larger site), and the storage yards (the location of the depleted UF_6 cylinders within the site). This section describes the affected environment at these sites, as well as the environmental settings assumed for the long-term storage, conversion, and disposal options.

3.1 PADUCAH SITE

The Paducah site is located in rural McCracken County, Kentucky, approximately 10 miles (16 km) west of the city of Paducah and 3.6 miles (6 km) south of the Ohio River (Figure 3.1). The Paducah site includes 3,423 acres (1,386 ha) surrounded by an additional 2,781 acres (1,125 ha) owned by DOE but managed by the State of Kentucky as part of the West Kentucky Wildlife Management Area (Martin Marietta Energy Systems [MMES] 1994b). According to a 1953 agreement granting the land to the Kentucky Department of Fish and Wildlife Resources, DOE can use any or all of this land whenever the need arises (MMES 1990). The city of Paducah is the largest urban area in the six counties surrounding the site. The six-county area is primarily rural, with industrial uses accounting for less than 5% of land use.

The Paducah Gaseous Diffusion Plant (PGDP) occupies a 750-acre (303-ha) complex within the Paducah site and is surrounded by a security fence (Figure 3.1). The PGDP, previously operated by DOE and now operated by the USEC, includes 115 buildings with a combined floor space of approximately 8.2 million ft^2 (0.76 million m^2) (MMES 1990). The PGDP has operated since 1955.

In 1994, the Paducah site was placed on the EPA National Priorities List (NPL), a list of sites across the nation that have been designated by EPA as high priority for site remediation. The NPL designation was mainly due to groundwater contamination with trichloroethylene and technetium-99, first detected in 1988. Being placed on the NPL meant that the cleanup requirements of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) would be met in conducting remediation efforts at the Paducah site. Hazardous waste and mixed waste management at the Paducah site must comply with *Resource Conservation and Recovery Act* (RCRA) regulations, which are administered by the Commonwealth of Kentucky, Division of Waste Management. The RCRA regulations also address implementation of corrective (or remedial) actions for solid waste management units. Thus, both CERCLA and RCRA have requirements for remedial actions for contaminated environmental media. A Federal Facilities Agreement (FFA) has been developed to integrate CERCLA/RCRA requirements into a single remediation procedure for the

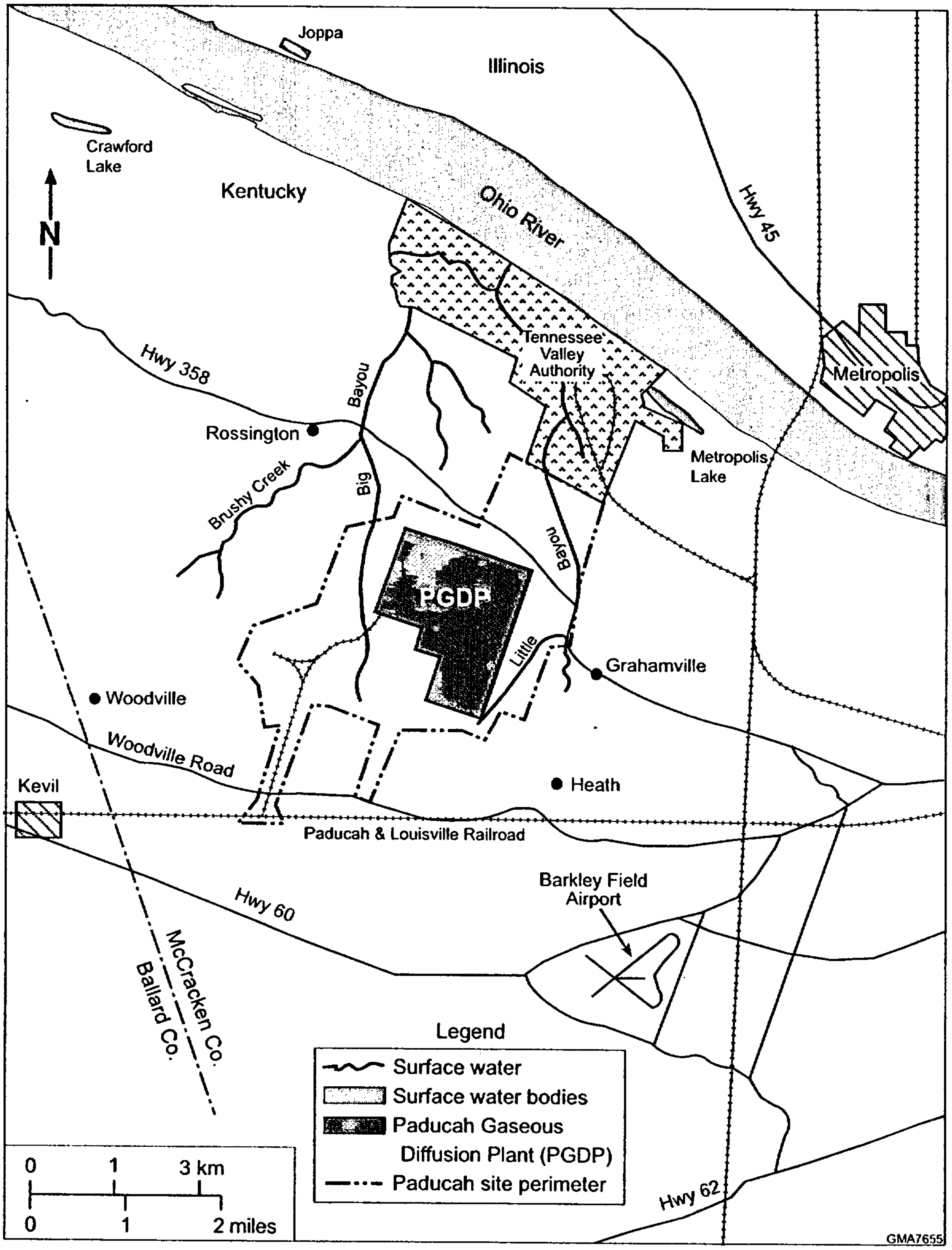

FIGURE 3.1 Regional Map of the Paducah Site Vicinity (Source: Adapted from LMES 1996a)

Paducah site. The discussion of affected environment in this PEIS focuses on conditions and contaminants pertinent to depleted UF_6 cylinder management. Some sitewide information from ongoing CERCLA/RCRA investigations is also included to put environmental conditions in the current depleted UF_6 cylinder storage areas into the context of sitewide conditions.

3.1.1 Cylinder Yards

The Paducah site has 13 yards used to store cylinders of DOE-generated depleted UF_6 (Table 3.1; Figure 3.2). The yards encompass approximately 13 acres (5.3 ha) and store 28,351 cylinders containing depleted UF_6. Nine of the Paducah storage yards have gravel bases. The C-745-F yard (F-yard) is located on a former building foundation. The C-745-S yard (S-yard), C-745-G yard (G-yard), and C-745-T yard (T-yard) are newly constructed with concrete bases.

TABLE 3.1 Locations of Cylinders of DOE-Generated Depleted UF_6 at the Paducah Site[a]

Yard	Area (ft^2)	Number of Cylinders
C-745-A[b]	199,899	1,802
C-745-B[b]	471,630	1,185
C-745-C	439,902	227
C-745-D	47,628	401
C-745-F	156,000	4,090
C-745-G	405,000	5,733
C-745-K	180,000	4,023
C-745-L	312,000	4,624
C-745-M	120,000	902
C-745-N	180,000	1,629
C-745-P	96,000	1,735
C-745-S	130,000	2,000
C-745-T	485,600	0
Total		28,351

[a] Locations of cylinders as of May 1996.

[b] USEC-leased yard with DOE cylinders in storage.

Source: Cash (1996).

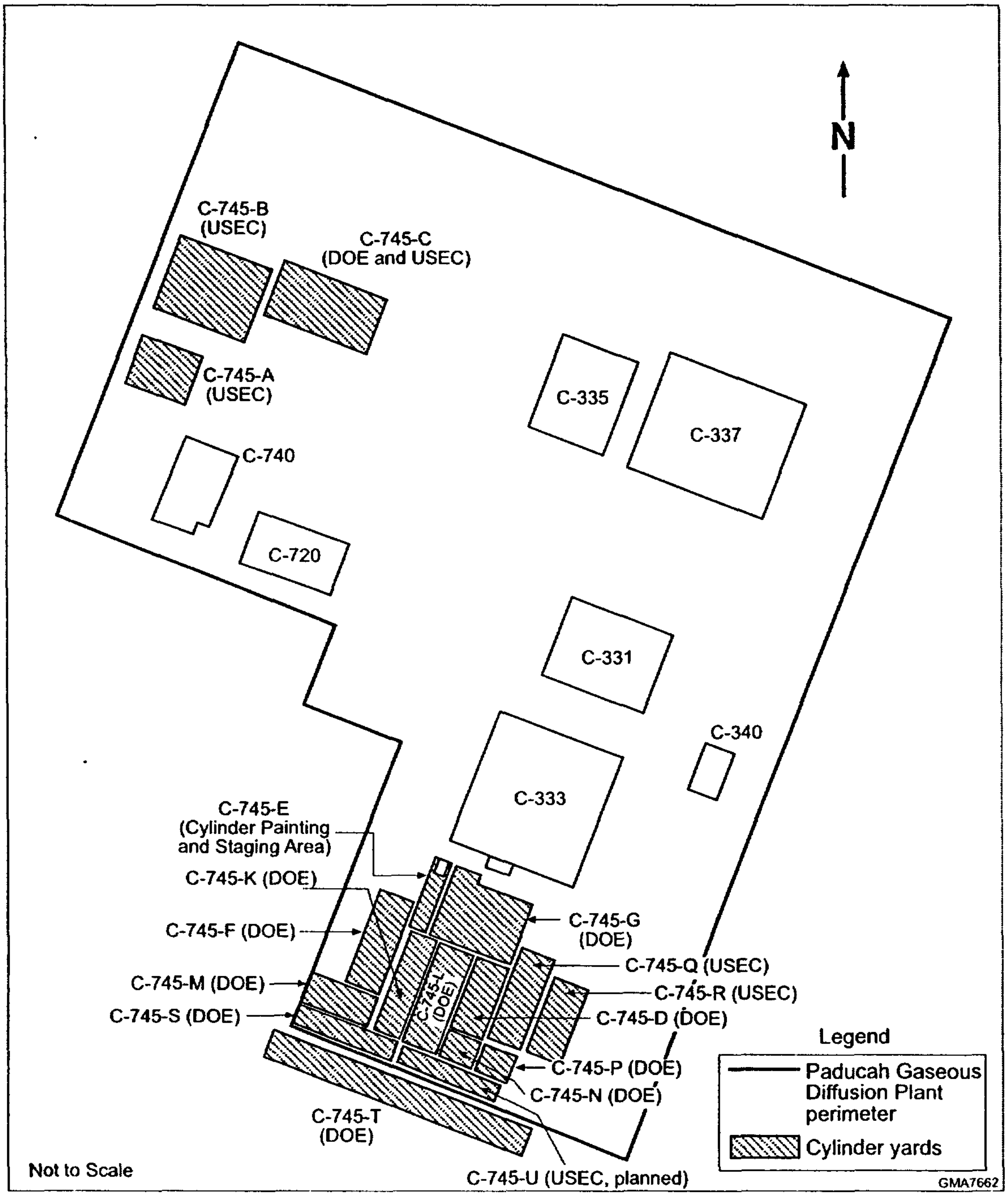

FIGURE 3.2 Locations of Cylinder Yards at the Paducah Site That Are Used to Store DOE Cylinders (Source: Adapted from DOE 1995c and Cash 1997)

The C-745-T (T-yard) was originally constructed outside the PGDP boundary but within the site perimeter. The PGDP boundary and fencing have been expanded to include the T-yard. The remaining cylinder yards will be rebuilt with concrete bases, starting with the C-745-K, C-745-L, C-745-M, C-745-N, and C-745-P yards (K-, L-, M-, N-, and P-yards). Cylinders are being restacked during relocation onto the newly constructed yards.

In addition to the DOE-generated cylinders, approximately 6,600 USEC-generated cylinders are stored in yards C-745-C, E, Q, and R (see Figure 3.2; DOE and USEC 1998a). Cylinder yard C-745-E is actually a cylinder staging area where cylinders are stored only temporarily; the USEC cylinders in this yard will be moved to C-745-Q or -R yards. The three yards C-745-C, Q, and R have gravel bases. Reconstruction of these yards with concrete bases is planned to follow the completion of reconstruction of the gravel yards currently storing DOE-generated cylinders (DOE and USEC 1998a). On the basis of a June 1998 Memorandum of Agreement, ownership and management of approximately 2,000 additional cylinders will be transferred from USEC to DOE between 1999 and 2004 (DOE and USEC 1998b). For purposes of analysis, this PEIS assumes that these cylinders will be located in yards C-745-C, Q, or R at the Paducah site.

One breached cylinder was identified in F-yard in November 1992. The small hole (about 1/16 in. × 2 in. [0.16 cm × 5 cm]) was attributed to handling damage, and a permanent patch was subsequently applied. In 1996, a steel engineered patch was welded onto another cylinder at the Paducah site. No material was thought to have been lost from either of these cylinders.

3.1.2 Site Infrastructure

The Paducah site is located in an area with an established transportation network. The area is served by two interstate highways, several U.S. and state highways, several rail lines, and a regional airport.

All water used by the site is obtained from the Ohio River through an intake at the steam plant near the Shawnee Power Plant north of the site. Before use, the water is treated on-site. Current water usage is approximately 15 million gal/d (57 million L/d). The maximum site capacity is 30 million gal/d (115 million L/d) (DOE 1996g).

Electric Energy, Inc., supplies electric power to the Paducah site. The current electrical need is 1,564 MW, with a maximum capacity of 3,040 MW. The coal system uses 82 tons (74 metric tons) per day, with a maximum capacity of 180 to 200 tons (160 to 180 metric tons) (DOE 1996g).

3.1.3 Ambient Air Quality and Airborne Emissions

The affected environment for air quality at the Paducah site is generally considered to be the Air Quality Control Region (AQCR) designated by the EPA: the Paducah (Kentucky) — Cairo (Illinois) Interstate AQCR in EPA Region 4. This AQCR includes McCracken County, Kentucky, in which the Paducah site is located. The EPA classifies McCracken County as an attainment area for all six National Ambient Air Quality Standards (NAAQS) criteria pollutants — carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter (PM_{10}, particles with a mean diameter of 10 μm or less), ozone (O_3), nitrogen oxides (NO_x), and lead (Pb). An attainment area for a criteria pollutant is an area that has an ambient air concentration of the pollutant below the corresponding standard.

The Commonwealth of Kentucky has adopted ambient air quality standards that specify maximum permissible short-term and long-term concentrations of various contaminants (Table 3.2). These standards are generally the same as the national standards. In addition to standards for criteria pollutants, the Kentucky Department of Environmental Protection (KDEP) has adopted rules governing new or modified sources emitting toxic air pollutants ("General Standards of Performance," *Kentucky Administrative Regulations*, Title 401, Chapter 63, Regulation 022 [401 KAR 63:022]), as well as standards for the hazardous air pollutants regulated by the National Emission Standards for Hazardous Air Pollutants (NESHAPS) (40 CFR Part 61).

DOE has responsibility for four air emission sources at the Paducah site, none of which involve the release of radiological effluents. The Paducah site is not required to conduct ambient air monitoring. DOE activities at the site in 1996 released quantities of criteria and hazardous air pollutants (HAPs) well below the amounts that would cause them to be classified by the *Clean Air Act* as a major source (LMES 1997c). An aggregate emission of 100 tons of any single criteria pollutant is required for the DOE operations to be classified as a major source. Emissions of criteria pollutants from cylinder refurbishment (grit blasting and painting) amounted to about 4.5 tons of particulate and 3.4 tons of volatile organic compounds (VOCs). Another 12 tons of VOCs may have been released from inactive closed landfills. In all, a total of as much as 16.6 tons of VOCs may have been emitted. The largest source of HAPs, a contaminated groundwater treatment facility, produced 1.4 tons of trichloroethylene, compared with the 10 tons of emissions of a single HAP necessary for major source designation.

3.1.4 Geology and Soil

3.1.4.1 Topography, Structure, and Seismic Risk

The topography of the Paducah site is relatively flat; within the boundaries of the PGDP security fence, the maximum difference in elevation is about 10 ft (3 m) (ERC/EDGe 1989). The site is underlain by bedrock of limestone and shale. Several zones of faulting occur in the vicinity of the site (Argonne National Laboratory [ANL] 1991a).

TABLE 3.2 Kentucky Ambient Air Quality Standards

Pollutant	Primary Standard	Secondary Standard
Carbon monoxide (CO)		
1-hour average	35 ppm[a]	35 ppm
8-hour average	9 ppm[a]	9 ppm
Sulfur dioxide (SO_2)		
3-hour average	–	0.50 ppm[a]
24-hour average	0.14 ppm[a]	–
Annual average	0.03 ppm	–
Particulate matter (PM_{10})		
24-hour average[b]	150 $\mu g/m^3$	150 $\mu g/m^3$
Annual arithmetic mean	50 $\mu g/m^3$	50 $\mu g/m^3$
Ozone (O_3)		
1-hour average	0.12 ppm	0.12 ppm
Nitrogen dioxide (NO_2)		
Annual average	0.05 ppm	0.05 ppm
Lead (Pb)		
Quarterly average	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$
Hydrogen sulfide		
Maximum 1-hour average	–	14 $\mu g/m^3$ (0.01 ppm)[a]
Gaseous fluorides (as HF)		
Annual arithmetic mean, not to exceed	0.5 ppm	–
Maximum 1-month average	–	1.00 ppb[a]
Maximum 1-week average	–	2.00 ppb[a]
Maximum 24-hour average	1.0 ppm[a]	3.50 ppb[a]
Maximum 12-hour average	–	4.50 ppb[a]
Total fluorides[c]		
Average concentration of monthly samples over growing season (not to exceed 6 consecutive months)	–	40 ppm (w/w)
2-month average	–	60 ppm (w/w)
1-month average	–	80 ppm (w/w)
Odors	At any time when one volume unit of ambient air is mixed with seven volume units of odorless air, the mixture must have no detectable odor.	

[a] Average not to be exceeded more than once per year.

[b] Standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 $\mu g/m^3$, as determined in accordance with Appendix K of 40 CFR Part 50, is equal to or less than one.

[c] Concentrations not to be exceeded on a dry weight basis (as fluoride ion) in and on forage for consumption by grazing ruminants; w/w = weight for weight.

Source: DOE (1996g).

The largest recorded earthquake in the region occurred in 1812 and was centered in the New Madrid fault zone. This earthquake had a magnitude of 7.3, and the epicenter was 60 miles (96 km) southwest of the site (LMES 1997f). This earthquake completely destroyed the town of New Madrid, Missouri.

The seismic hazards at the Paducah site have been studied extensively. The safety analysis report (SAR) for this site, completed in March 1997, provided comprehensive analyses and discussions of seismic hazards at the site (see Sections 1.5 and 3.3 of the SAR; LMES 1997f). The analyses considered the possibility of large-magnitude earthquakes similar to the New Madrid earthquakes of 1811–1812. The analyses performed by DOE were independently reviewed by the U.S. Geological Survey (USGS). The independent review by the USGS indicated that the seismic sources, recurrence rates, maximum magnitudes, and the attenuation functions used in the SAR analyses were representative of a wide range of professional opinion and were suitable for obtaining probabilistically based seismic hazard estimates. Because of the proximity of the site to the New Madrid seismic zone, special deterministic analyses were also performed to estimate the ground motions at the site in the case of recurrence of an earthquake of the same magnitude as the 1811–1812 New Madrid earthquakes. The results of the deterministic analyses were similar to the probabilistic seismic hazard results for the probabilities associated with the recurrence of the New Madrid earthquake of 1811–1812. The results also indicated that continued storage of depleted UF_6 cylinders at the Paducah site is safe.

For the Paducah site, the evaluation basis earthquake (EBE) was designated by DOE to have a return period of 250 years. A detailed analysis indicated that the peak ground motion for the EBE was 0.15 times the acceleration of gravity (LMES 1997f). An earthquake of this size would have an equal probability of occurring any time during a 250-year period.

For this PEIS, the analyses of earthquake-initiated accidents at the Paducah site were based on the analyses and results provided in the SAR (LMES 1997f; see also Appendix C, Section C.4.2). A spectrum of accidents was considered, ranging from those having a high probability of occurrence but low consequences to those having high consequences but a low probability of occurrence. Natural phenomena accidents including earthquakes, floods, and tornadoes were among the accidents considered.

3.1.4.2 Soil

Substances in soil possibly associated with cylinder management activities would be uranium and fluoride compounds, which could be released if breached cylinders or faulty valves were present. For the evaluation of ongoing activities at the Paducah site, the purpose of soil sampling has been to identify the accumulation of any airborne pollutants; thus, annual soil samples have been collected from 10 off-site locations: four at the site boundary, four at distances of 5 miles

(8 km) beyond the boundary, and two at more remote locations to characterize background levels (LMES 1996a; MMES 1994b). In 1994, uranium concentrations for the 10 sampling locations ranged from 2.0 to 5.8 μg/g; plant boundary concentrations ranged from 2.3 to 4.9 μg/g (LMES 1996a).

Because of a transfer of responsibility for air point sources from DOE to USEC, concentrations of nonradiological parameters in soil at these sampling locations are no longer reported (LMES 1996a); however, analytical results for polychlorinated biphenyls (PCBs) and metals are available for previous years. In 1993, no detectable concentrations of PCBs were found in any of the samples, but elevated concentrations of bismuth, lead, manganese, thallium, and thorium were detected in several samples (MMES 1994b). Fluoride was not analyzed in soil samples, but it is naturally occurring in soils and of low toxicity.

As part of ongoing CERCLA/RCRA investigations of Paducah site operable units, several areas of soil have been identified as contaminated with radionuclides and chemicals such as PCBs and metals. However, this contamination is not associated with the depleted UF_6 cylinder yards, and remediation is being implemented as a part of ongoing CERCLA/RCRA activities at the site.

3.1.5 Water Resources

The affected environment for water resources consists of surface water within and in the vicinity of the site boundary and groundwater beneath the site. Analyses of surface water, stream sediment, and groundwater samples have indicated the presence of some contamination resulting from previous gaseous diffusion plant operations.

3.1.5.1 Surface Water

Big Bayou Creek is located on the west side of the Paducah site and Little Bayou Creek on the east side (Figure 3.1). These two streams join north of the site and discharge to the Ohio River. Flows in Big Bayou Creek and Little Bayou Creek fluctuate greatly as a result of precipitation. During most of the year, flows in both streams are derived primarily from plant effluents. All water used by the site is obtained from the Ohio River through an intake north of the site (ANL 1991a).

Most of the liquid effluents from the Paducah site consist of cooling water, although a variety of liquid wastes are produced by activities such as metal finishing, uranium recovery, and facility cleaning (Rogers et al. 1988a). In addition to these discharges, a large variety of conventional liquid wastes enter the surface water system, including treated domestic sewage, steam plant wastewater, and coal pile runoff.

All effluent discharges are under the Kentucky Pollutant Discharge Elimination System (KPDES). At the present time, there are a total of 15 outfalls. Ten outfalls are authorized to USEC (KY0102083); five outfalls are authorized to DOE (KY000409). Of the DOE outfalls, three are to

Big Bayou Creek and one is to an unnamed tributary of Little Bayou Creek. The average discharge of wastewater to Big Bayou Creek is approximately 4 million gal/d (15 million L/d). The average discharge to the Ohio River through Big Bayou and Little Bayou Creeks is about 4.1 million gal/d (16 million L/d). The average flow in the Ohio River is 1.7×10^{11} gal/d (6.5×10^{11} L/d).

Monitoring of surface water in 1995 and 1996 indicated that the maximum average concentration of uranium was 0.012 mg/L in the downstream portion of Little Bayou Creek (LMES 1997a; 1997c). The maximum average concentration of fluoride was < 0.224 mg/L in the north/south diversion ditch within the PGDP (MMES 1994e). Comparable fluoride data were not reported for 1994, 1995, or 1996 (LMES 1996a, 1997a,c).

The KPDES-permitted outfalls are monitored for inorganic substances and about 45 organic substances, including PCBs. The monitoring frequency for most substances is two to four times per year; several substances are monitored monthly or quarterly to comply with KPDES permit requirements. The maximum average uranium concentration in effluents from the DOE outfalls from 1994 through 1996 was 0.037 mg/L (LMES 1996a, 1997a,c). In both 1994 and 1995, two USEC-leased outfalls received a "Notice of Violation" for PCB exceedances.

Sediment samples are also collected annually from six locations and analyzed for uranium, PCBs, and metals. In 1993, concentrations of uranium and PCBs were detected at significantly higher levels than background in Little Bayou Creek (sampling location SS2). The uranium concentration of 200 mg/kg at the measuring location was two times higher than in 1992. The PCB concentration also increased from 0.9 mg/kg in 1992 to 2.0 mg/kg in 1993. However, levels decreased in 1994 (22 mg/kg maximum uranium concentration; 1.4 mg/kg maximum PCB concentration) (LMES 1996a) and again in 1995 (13 mg/kg maximum uranium concentration; < 0.1 mg/kg maximum PCB concentration) (LMES 1997a). In 1996, the uranium concentration in sediment at location SS2 was 44 mg/kg; the PCB concentration was 1.3 mg/kg. A new sampling location (SS29) was added on Little Bayou Creek closer to the PGDP. The uranium concentration at this location was 360 mg/kg; no PCB value was reported (LMES 1997c).

3.1.5.2 Groundwater

Two near-surface aquifers are of importance at the Paducah site. The upper aquifer is a shallow, perched-water aquifer composed of sands and sand and clay mixtures that are discontinuous (Rogers et al. 1988a). Water yields from this aquifer are very low, and the hydraulic gradient (change in water elevation with distance) is difficult to detect. Water movement is generally in a northeasterly direction at less than 0.1 ft/yr (0.3 m/yr).

The lower aquifer is a good-yielding gravel aquifer that has an upper surface at a depth of about 39 ft (12 m) and a thickness that ranges from about 20 to 59 ft (6 to 18 m). This aquifer appears to be continuous beneath the Paducah site. Hydraulic conductivity is estimated to be 0.0001 to 1 cm/s for the regional gravel aquifer and 0.00001 to 0.01 cm/s for the upper continental deposits (sands). Water movement is 2 to 5 ft/yr (0.6 to 1.5 m/yr) and variable in direction (Rogers et al. 1988a).

On-site and off-site groundwater sampling for the Paducah site is performed in about 200 monitoring wells, residential wells, and Tennessee Valley Authority wells. Off-site sampling is performed to monitor three separate trichloroethylene and technetium plumes first detected in 1988 (LMES 1996a) (Figure 3.3). The Paducah site has provided a municipal water supply to all residents whose wells are within the area of groundwater contamination from the site; resident wells that are no longer sampled are locked and capped.

Although the magnitude of groundwater contamination originating from the Paducah site is greatest for trichloroethylene and technetium, the primary drinking water standards or derived concentration guidelines for several other inorganic, volatile organic, and radionuclide substances were also exceeded in one or more of the monitoring wells on or near the Paducah site in monitoring occurring from 1993 through 1996 (MMES 1994b; LMES 1996a, 1997a,c). (The derived concentration guideline is equivalent to the MCL; it is the concentration of a radionuclide that under conditions of continuous exposure for 1 year would result in an effective dose equivalent of 4 mrem [EPA 1996; DOE Order 5400.5]). The uranium guideline of 20 ug/L was exceeded in four wells, and the fluoride guideline of 4 mg/L was exceeded in two wells. The wells with uranium and fluoride exceedances were not located near the cylinder yards.

3.1.6 Biotic Resources

3.1.6.1 Vegetation

The Paducah site includes the highly developed PGDP, which has few natural vegetation communities. The DOE property between the PGDP and the West Kentucky Wildlife Management Area consists primarily of open, frequently mowed grassy areas. The DOE property also includes several small upland areas of mature forest, old field, and transitional habitats. The banks of Big Bayou Creek and Little Bayou Creek support mature riparian forest with river birch, black willow, and cottonwood (ANL 1991a). The West Kentucky Wildlife Management Area contains wooded areas from early and mid-successional stages to mature forest communities. Nonforested areas are managed by controlled burns, mowing, and planting.

3.1.6.2 Wildlife

The habitats at the Paducah site support a relatively high diversity of wildlife species. Ground-nesting species include the white-footed mouse, bobwhite, and eastern box turtle. Big Bayou Creek, upstream of the Paducah site, supports aquatic fauna indicative of oxygen-rich, clean water,

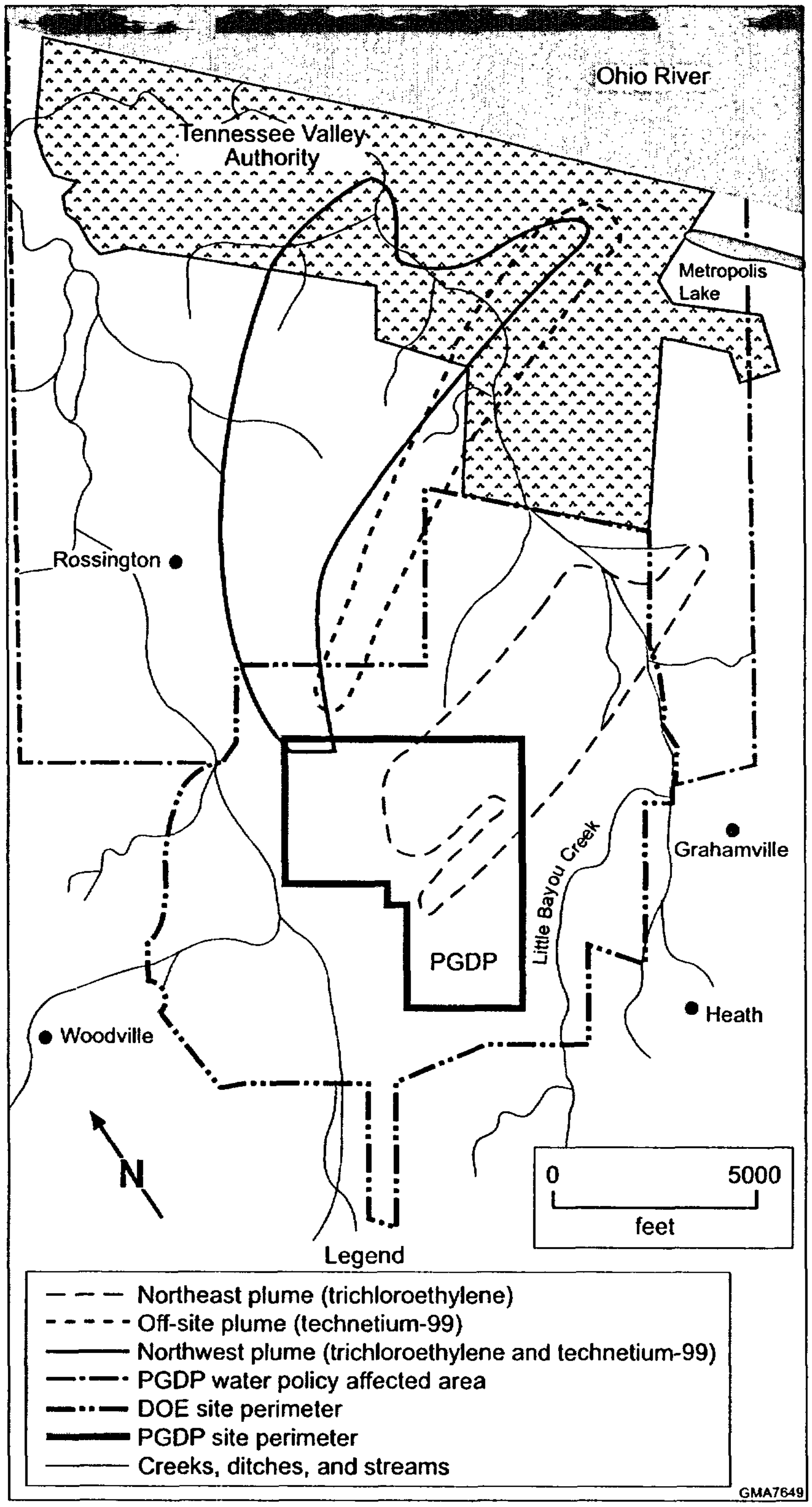

FIGURE 3.3 Locations of Contaminated Groundwater Plumes at the Paducah Site (Source: Adapted from MMES 1994b)

including 14 fish species. Aquatic species just downstream of the Paducah site discharge points include 11 fish species (LMES 1997c). The density and diversity of aquatic organisms are generally lower near the outfalls than upstream areas for both Little Bayou Creek and Big Bayou Creek (DOE 1994b).

3.1.6.3 Wetlands

Although no wetlands are identified on the PGDP by the National Wetlands Inventory, approximately 5 acres of jurisdictional wetlands have been identified in drainage ditches scattered throughout the PGDP (ANL 1991a; CDM Federal Programs Corporation 1994; Sadri 1995). Outside the PGDP, a large number of wetlands are scattered throughout the Paducah site. These include forested wetlands, ponds, wet meadows, vernal pools, and wetlands converted to agriculture (U.S. Department of the Army 1994c). Palustrine forested wetlands occur extensively along the banks of Big Bayou Creek and Little Bayou Creek. The National Wetlands Inventory identifies many wetlands on the Paducah site, primarily ponds and forested wetlands. A forested wetland dominated by tupelo trees in the West Kentucky Wildlife Management Area has been designated by the Kentucky Nature Preserves Commission and Kentucky Department of Fish and Wildlife as an area of ecological concern (DOE 1996g).

3.1.6.4 Threatened and Endangered Species

No federal-listed plant or animal species are known to occur on the Paducah site. However, the Indiana bat (federal- and state-listed as endangered) has been found near the confluence of Bayou Creek and the Ohio River 3 miles north of the PGDP. Potential habitat occurs on the Paducah site outside the PGDP (U.S. Department of the Army 1994b) and in adjacent wooded areas. State-listed species known to occur on the Paducah site include the compass plant, which is listed by the Kentucky State Nature Preserve Commission as threatened. The lake chubsucker, listed by the Nature Preserve Commission as threatened, is known from early, but not recent, surveys of Big Bayou Creek and Little Bayou Creek. State-listed species of special concern that occur on or near the Paducah site include Bell's vireo, cream wild indigo, and Northern crawfish frog. The presence of state-listed species and requirements for consultation with the Kentucky State Nature Preserve Commission would be determined in site-specific environmental analyses.

3.1.7 Public and Occupational Health and Safety

3.1.7.1 Radiation Environment

Operations at the Paducah site result in radiation exposures of both on-site workers and off-site members of the general public (Table 3.3). Exposures of on-site workers generally are

TABLE 3.3 Estimated Radiation Doses to Members of the General Public and to Cylinder Yard Workers at the Paducah Gaseous Diffusion Plant

Receptor	Radiation Source	Dose to Individual (mrem/yr)
Member of the general public (MEI)[a]	Routine site operations	
	Airborne radionuclides	0.0023[b]
	Waterborne radionuclides	0.67[c]
	Direct gamma radiation	1[d]
	Ingestion of drinking water	0[e]
	Ingestion of wildlife	0.0023[f]
Cylinder yard worker	External radiation	16 – 56[g]
Member of public or worker	Natural background radiation and medical sources	360[h]
DOE worker limit		2,000[i]

[a] The maximally exposed individual (MEI) was assumed to reside at an off-site location that would yield the largest dose. An average person would receive a radiation dose much less than the values shown in this table.

[b] Radiation doses from airborne releases were calculated by using an air dispersion model and considered exposure from external radiation, inhalation, and ingestion of foodstuffs. The MEI is located approximately 1,170 m (3,836 ft) north-northeast of the plant site (LMES 1997c).

[c] Radiation doses could result from incidental ingestion of contaminated sediment and inhalation of contaminated particles from fishing, hunting, and other recreational activities in Little Bayou Creek (LMES 1997c).

[d] Radiation doses could result from hunting activities on the banks of Little Bayou Creek (LMES 1997c).

[e] According to the results of a 1990 survey, there was no reported use of surface water. Also, contaminated well water is not used because all residents in that area receive city water (LMES 1996a).

[f] Radiation doses could result from ingestion of the edible portion of two average-weight deer containing the maximum detected concentrations of radionuclides (LMES 1997c).

[g] Range of annual average doses from years 1990 through 1995 (Hodges 1996).

[h] Average dose to a member of the U.S. population as estimated in Report No. 93 of the National Council on Radiation Protection and Measurements (NCRP 1987b).

[i] DOE administrative procedures limit DOE workers to 2,000 mrem/yr (DOE 1992), whereas the regulatory dose limit for radiation workers is 5,000 mrem/yr (10 CFR Part 835).

associated with handling of radioactive materials used in the on-site facilities and with inhalation of radionuclides released from processes conducted on-site. Members of the off-site general public are exposed to radionuclides discharged from on-site facilities through airborne and/or waterborne emissions.

The total radiation dose to the maximally exposed individual (MEI) of the general public is estimated to be 1.7 mrem/yr, which is much lower than the maximum radiation dose limit set for the general public of 100 mrem/yr from operation of a DOE facility (DOE Order 5400.5). The average external radiation dose for cylinder yard workers has ranged from 16 to 56 mrem/yr (Hodges 1996) in the past few years and has been well below the maximum dose limit of 5,000 mrem/yr set for radiation workers (10 CFR Part 835). All of these exposures are a very small fraction of the 360 mrem/yr dose received by the general public and workers from natural background and medical sources (Table 3.3).

3.1.7.2 Chemical Environment

Estimated hazard quotients for members of the general public under existing environmental conditions near the Paducah site are presented in Table 3.4. The hazard quotient represents a comparison of estimated human intake levels with intake levels below which adverse effects are very unlikely to occur (see Chapter 4). The estimated hazard quotients indicate that exposures near the Paducah site are generally a small fraction of those that might be associated with adverse health effects. An exception is groundwater, where hazard quotients for several substances could exceed the threshold of 1. However, because this groundwater is not a drinking water source, there is no exposure. The residents near the PGDP whose wells have been contaminated have been provided with alternate water sources.

The Occupational Safety and Health Administration (OSHA) has proposed permissible exposure limits (PELs) for uranium compounds and HF in the workplace (29 CFR Part 1910, Subpart Z, as of March 1998), as follows: 0.05 mg/m^3 for soluble uranium compounds; 2.5 mg/m^3 for HF. Paducah worker exposures are kept below these limits.

3.1.8 Socioeconomics

The socioeconomic environment of the Paducah site was assessed in terms of regional economic activity, population and housing, and local public finances. The region of influence (ROI) consists of Ballard, Carlisle, Graves, Marshall, and McCracken Counties in Kentucky, and Massac County in Illinois; 93.1% of employees at the site currently reside in those counties, with 59.1% residing in McCracken County (DOE 1997a). Allison and Folga (1997) provide a listing of the counties, cities, and school districts within the ROI, together with supporting data for the socioeconomic characteristics described in this section.

TABLE 3.4 Estimated Hazard Quotients for Members of the General Public near the Paducah Site under Existing Environmental Conditions[a]

Environmental Medium	Parameter	Exposure Concentration	Estimated Chronic Intake (mg/kg-d)	Reference Level[b] (mg/kg-d)	Hazard Quotient[c]
Air[d,e]	Uranium	0.0078 µg/m^3	2.2×10^{-6}	0.0003	0.0074
	HF	0.096 µg/m^3	2.7×10^{-5}	0.02	0.0014
Soil[f]	Uranium	5.8 µg/g	7.7×10^{-5}	0.003	0.026
Surface water[e]	Uranium	16 µg/L	8.7×10^{-6}	0.003	0.003
	Fluoride	< 224 µg/L	1.2×10^{-4}	0.06	0.002
Sediments[e]	Uranium	360 µg/g	6.2×10^{-6}	0.003	0.033
	Aroclor 1254	1.4 µg/g	3.8×10^{-7}	0.00002	0.019
	Aroclor 1254[g]	1.4 µg/g	5.5×10^{-8}	2.0 (slope factor)	1.1×10^{-7} (cancer risk)
Groundwater[h]	Uranium	20 µg/L	5.7×10^{-4}	0.003	≥ 0.19
	Fluoride	4,000 µg/L	1.1×10^{-1}	0.06	≥1.9

[a] The receptor was assumed to be a long-term resident near the site boundary or other off-site monitoring location that would have the highest concentration of the contaminant being addressed; reasonable maximum exposure conditions were assumed. Only the exposure pathway contributing the most to intake levels was considered (i.e., inhalation for air and ingestion for soil, sediment, surface water, and groundwater). Residential exposure scenarios were assumed for air, soil, and groundwater analyses; recreational exposure scenarios were assumed for surface water and sediment analyses.

[b] The reference level is an estimate of the daily human exposure level that is likely to be without an appreciable risk of deleterious effects. The reference levels used in this assessment are defined in Appendix C. For carcinogens, the slope factor is also given; slope factors in units of $(mg/kg\text{-}d)^{-1}$ are multiplied by lifetime average intake to estimate excess cancer risk.

[c] The hazard quotient is the ratio of the intake of the human receptor to the reference level. A hazard quotient of less than 1 indicates that adverse health effects resulting from exposure to that chemical alone are highly unlikely. For carcinogens, the cancer risk (intake × slope factor) is also given. Increased cancer risks between 10^{-6} and 10^{-4} are considered tolerable at hazardous waste sites; risks less than 10^{-6} are considered negligible.

[d] Gross alpha was used as a surrogate measure of uranium concentration.

[e] Exposure concentrations are the maximum annual averages for all monitoring locations (MMES 1994b; LMES 1996a; 1997a, 1997c).

[f] Maximum uranium concentration from 10 plant boundary and off-site soil monitoring locations (LMES 1996a).

[g] Parameters analyzed for carcinogenic effects; all other parameters were analyzed for noncarcinogenic effects.

[h] Data are for monitoring and residential wells located on or near DOE property at the Paducah site (the residential wells are not currently used for drinking water). Several additional substances exceeded reference levels between 1993 and 1996 (Section 3.1.5.2); listed here are only substances of particular interest for this PEIS. Well-specific concentrations were not available; the exposure concentrations given are actually drinking water standards or guidelines. Hazard indices based on well-specific concentrations could exceed those presented.

3.1.8.1 Regional Economic Activity

Employment in the ROI rose relatively steadily between 1980 and 1995, growing from 72,300 to 78,900, an increase of 9.1%. Within the ROI, the largest percent employment increase occurred in McCracken County (13.8%), which had 51% of total ROI employment in 1995. The U.S. Bureau of Economic Analysis (BEA) projects a 1.9% increase in employment in the ROI over the period 1995 to 2020 (1,500 jobs), with the largest increase expected in McCracken County (3.5%, 1,400 jobs) (BEA 1996a). Unemployment in the ROI in 1996 was 5.4% (Allison 1996). Employment at the Paducah site in 1995 was 1,700 (DOE 1997a), amounting to approximately 2.2% of total employment in the ROI.

Personal income in the ROI rose relatively steadily between 1980 and 1995, growing from $1.6 billion to $1.8 billion, an increase of 13%. The largest percent increase occurred in McCracken County (20%), which had 46% of total ROI personal income in 1995. The BEA projects a 31.9% increase in ROI personal income from 1995 to 2020 ($0.6 billion), with the largest increase in McCracken County (33%, $0.3 billion) (BEA 1996a).

3.1.8.2 Population

The ROI experienced small increases in population over the period 1980 to 1995, with total population growing from 150,271 to 153,000, an increase of 1.8%. The 1995 ROI population was concentrated in McCracken County (41.7%). The BEA projects the ROI population as a whole to increase by 9,600 (6.3%) from 1995 to 2020, with the largest increase in McCracken County (7.7%, 4,900 people) (BEA 1996a).

3.1.8.3 Housing

Between 1980 and 1995, the number of housing units in the ROI increased by 9.6%, from 61,000 to 66,900. McCracken County had 41% of the total housing units. Based on BEA (1996a) population forecasts for 1995 to 2020 and U.S. Bureau of the Census (1994) statistics, the total number of vacant owner-occupied units in the ROI is expected to increase from 4,460 to 4,880 and the total number of vacant rental units from 1,520 to 1,620.

3.1.8.4 Public Finance

The financial characteristics of local public jurisdictions included in the ROI are summarized in Table 3.5. Data are shown for the major revenue and expenditure categories and for the annual fiscal balance of the general fund account for cities, counties, and school districts.

TABLE 3.5 Summary of Financial Characteristics for the Paducah Site County, City, and School District Regions of Influence

Category	Finances[a] ($ million) ROI Counties	Finances[a] ($ million) ROI Cities	Category	Finances[a] ($ million) ROI School Districts
Revenues			**Revenues**	
Local sources	8.8	6.5	Local sources	23.8
Fines, fees, permits, etc.	1.3	14.5	State sources	67.2
Intergovernmental	1.3	6.1	Federal sources	4.1
Other	0.8	2.6	Other	16.5
Total	12.3	29.7	Total	111.6
Expenditures			**Expenditures**	
General government	6.3	4.7	Administration	2.2
Safety, health, community services	6.0	16.1	Instruction	67.1
			Services	8.5
Debt service	0.0	0.1	Physical plant	9.8
Other financing sources	1.4	-5.6	Other	24.4
Total	14.0	15.3	Total	112.1
Revenues less Expenditures	-1.7	14.4	**Revenues less Expenditures**	-0.4

[a] Data for fiscal year ending June 30, 1995.

Sources: see Allison and Folga (1997).

3.1.9 Waste Management

The affected environment with respect to waste management is considered to be wastewater and solid waste generated at the Paducah site. Disposal of this waste is currently managed by USEC, including any waste generated from ongoing management of the DOE-generated depleted UF_6 cylinders currently in storage. The cylinder storage yards at Paducah currently generate only a very small amount of waste compared with the volume of waste generated from ongoing plant operations. Cylinder yard waste consists of small amounts of metal, scrapings from cylinder maintenance operations, potentially contaminated soil, and miscellaneous items.

The Paducah site generates wastewater, solid LLW, solid and liquid LLMW, nonradioactive hazardous waste, and nonradioactive nonhazardous solid waste. The site has an active program to minimize the generation of solid LLW, hazardous waste, and LLMW. Waste minimization efforts for radioactive waste include prevention of packaging material from entering radiological areas and replacement of wood pallets used in radiological areas. Hazardous waste and LLMW minimization actions include use of less chlorinated solvents, recycling of paint wastes, and compaction of PCB wastes. Solid waste minimization actions include recycling of paper and cardboard and off-site recycling of fluorescent bulbs and used batteries.

3.1.9.1 Wastewater

Wastewater at the Paducah site consists of nonradioactive sanitary and process-related wastewater streams, cooling water blowdown, and radioactive process-related liquid effluents. Wastewater is processed at on-site treatment facilities and is discharged to Big Bayou Creek or Little Bayou Creek through eight outfalls identified under the site KPDES permit #KY0004049. In 1993, the wastewater treatment system processed approximately 0.4 million gal/d (1.5 million L/d) of wastewater. The total capacity of the site wastewater control facilities is approximately 1.75 million gal/d (6.6 million L/d). About 23% of the capacity of wastewater treatment facilities is currently used.

In 1992, the wastewater discharge at the Paducah site was in compliance with KPDES permit requirements 99.5% of the time. A few exceedances occurred for total residual chlorine, trichloroethylene, pH, and total suspended solids (MMES 1994b). In 1994, the PCB effluent limits were exceeded 18 times in site wastewater discharges. These exceedances were addressed through existing site agreements with the state (LMES 1996a).

3.1.9.2 Solid Nonhazardous, Nonradioactive Waste

Solid waste — including sanitary refuse, cafeteria waste, industrial waste, and construction and demolition waste — is collected and disposed of at the on-site landfill, which consists of three cells. The first cell is closed and capped, the second is near capacity, and the third cell awaits final authorization from the Kentucky Division of Waste Management. The total capacity of the landfill is 26,000 yd^3 (20,000 m^3). The site solid waste generation rate for 1993 was 2,740 yd^3/yr (2,100 m^3/yr) (DOE 1996g).

3.1.9.3 Nonradioactive Hazardous and Toxic Waste

Nonradioactive waste that is considered hazardous waste according to RCRA or contains PCBs as defined under the TSCA requires special handling, storage, and disposal. The Paducah site generates hazardous waste — including spent solvents and heavy-metal-contaminated waste — and PCB-contaminated toxic waste. The site has a Kentucky Division of Waste Management RCRA Part B permit (#KY8890008982), which expires in 2001. The permit authorizes the Paducah site to treat and store hazardous waste in 10 treatment units, 16 tanks, and 4 container storage areas at the site. There are several additional 90-day storage areas for temporary storage of hazardous waste.

Approximately 99 yd^3 (76 m^3), or 209 tons (190 metric tons), of solid hazardous waste was generated in 1992. Certain hazardous/toxic wastes are sent to permitted off-site contractors for final treatment and/or disposal. Much of the hazardous/toxic waste load consists of PCB-contaminated waste. More than 370 yd^3 (280 m^3) of PCBs is used in electrical equipment at the Paducah site (MMES 1994b). Some liquid hazardous and/or mixed waste streams are shipped to the K-25 site for incineration in a TSCA incinerator, which has a capacity of 1,800 yd^3/yr (1,400 m^3/yr).

3.1.9.4 Low-Level Waste

LLW generated at the Paducah site is stored on-site pending shipment to a commercial facility in Tennessee for volume reduction. Solid LLW generated at the Paducah site includes refuse, sludge, and debris contaminated with radionuclides, primarily uranium and technetium. The site generated 2,450 yd^3 (1,870 m^3) of solid LLW in 1991 and 650 yd^3 (500 m^3) in 1992. As of 1995, the site had 4,380 yd^3 (3,350 m^3) of LLW in storage (DOE 1996g). Site wastewater treatment facilities can process up to 1,480 yd^3 (1,140 m^3) per year of aqueous LLW.

3.1.9.5 Low-Level Mixed Waste

LLW that contains PCBs or RCRA hazardous components is considered to be low-level mixed waste (LLMW). As of 1995, 243 yd^3 (186 m^3) of LLMW was in storage at the Paducah site. Of this total, 63 yd^3 (48 m^3) represents waste subject to land disposal restrictions. Solid LLMW generation in 1992 was 1,080 yd^3 (824 m^3). In 1992, approximately 560,000 lb (256,000 kg) of organic liquid was sent to the TSCA incinerator on the K-25 site. On-site capacity for storing LLMW containers at the Paducah site is 3,600 yd^3 (2,800 m^3). The site can treat up to 204 ft^3/yr (156 m^3/yr) of aqueous LLMW (DOE 1996g).

3.1.10 Cultural Resources

Thirty-two cultural resource sites are currently recorded within and immediately surrounding the PGDP. Twenty-two were recorded during surveys conducted in the 1970s and early 1980s, and 10 more were recently recorded during a cultural resources study consisting of a 20% stratified random sample survey for prehistoric and historic archaeological sites. Results of a sensitivity analysis, also conducted as part of the study, indicate that much of the area surrounding the fenced complex has a low or very low index of sensitivity, meaning there is a low probability of finding prehistoric sites near the developed area. However, scattered areas of high sensitivity are located along Little Bayou Creek and Big Bayou Creek; at least three prehistoric sites and one historic site are potentially eligible for the *National Register of Historic Places* (U.S. Department of the Army 1994a-b).

An inventory of historic buildings is planned but has not been conducted at the Paducah site. It is likely that buildings related to uranium enrichment and the gaseous diffusion process that supported atomic weapon manufacture or to activities at the Kentucky Ordnance Works could be eligible for the *National Register*. No cemeteries are located on the Paducah site.

No religious or sacred sites, burial sites, or resources significant to Native Americans have been identified at the Paducah site to date.

3.1.11 Minority and Low-Income Populations

The affected environment for assessing the potential for depleted UF_6 management activities to result in environmental justice impacts was based on data from the U.S. Bureau of the Census (1992a-b). The population residing within a 50-mile (80-km) radius of the Paducah site consists of 9.2% minorities and 19.0% persons with low income (see Appendix C, Section C.8.1).

3.2 PORTSMOUTH SITE

The Portsmouth site is located in Pike County, Ohio, approximately 22 miles (35 km) north of the Ohio River and 3 miles (5 km) southeast of the town of Piketon (Figure 3.4). The two largest cities in the vicinity are Chillicothe, located 26 miles (42 km) north of the site, and Portsmouth, 22 miles (35 km) south.

The Portsmouth site includes the Portsmouth Uranium Enrichment Complex (PUEC), a gaseous diffusion plant previously operated by DOE and currently operated by the USEC. The Portsmouth site occupies 3,708 acres (1,500 ha) of land, with an 800-acre (320-ha) fenced core area that contains the PUEC production facilities. The 2,908 acres (1,180 ha) outside of the core area consist of restricted buffers, waste management areas, plant management and administrative facilities, gaseous diffusion plant support facilities, and vacant land (MMES 1992b). The PUEC has operated since 1995.

Wayne National Forest borders the plant site on the east and southeast, and Brush Creek State Forest is located to the southwest, slightly over 1 mile (1.6 km) from the site boundaries. Forests account for over 60% of the land in Pike County and over 70% in Scioto County. Neither county has residential land uses exceeding 2% or industrial/commercial land uses exceeding 1%.

No land-use maps or comprehensive or master plans have been developed for either Pike County or Scioto County, although the city of Portsmouth is in the process of developing one. The Portsmouth facility has a master plan, which indicates that future land-use patterns on the site are expected to remain essentially the same as current conditions (MMES 1992b).

The Portsmouth site is not on the NPL; environmental remediation activities at the site are overseen under the provisions of RCRA. The discussion of affected environment in this PEIS focuses on conditions and contaminants pertinent to depleted UF_6 cylinder management. Some

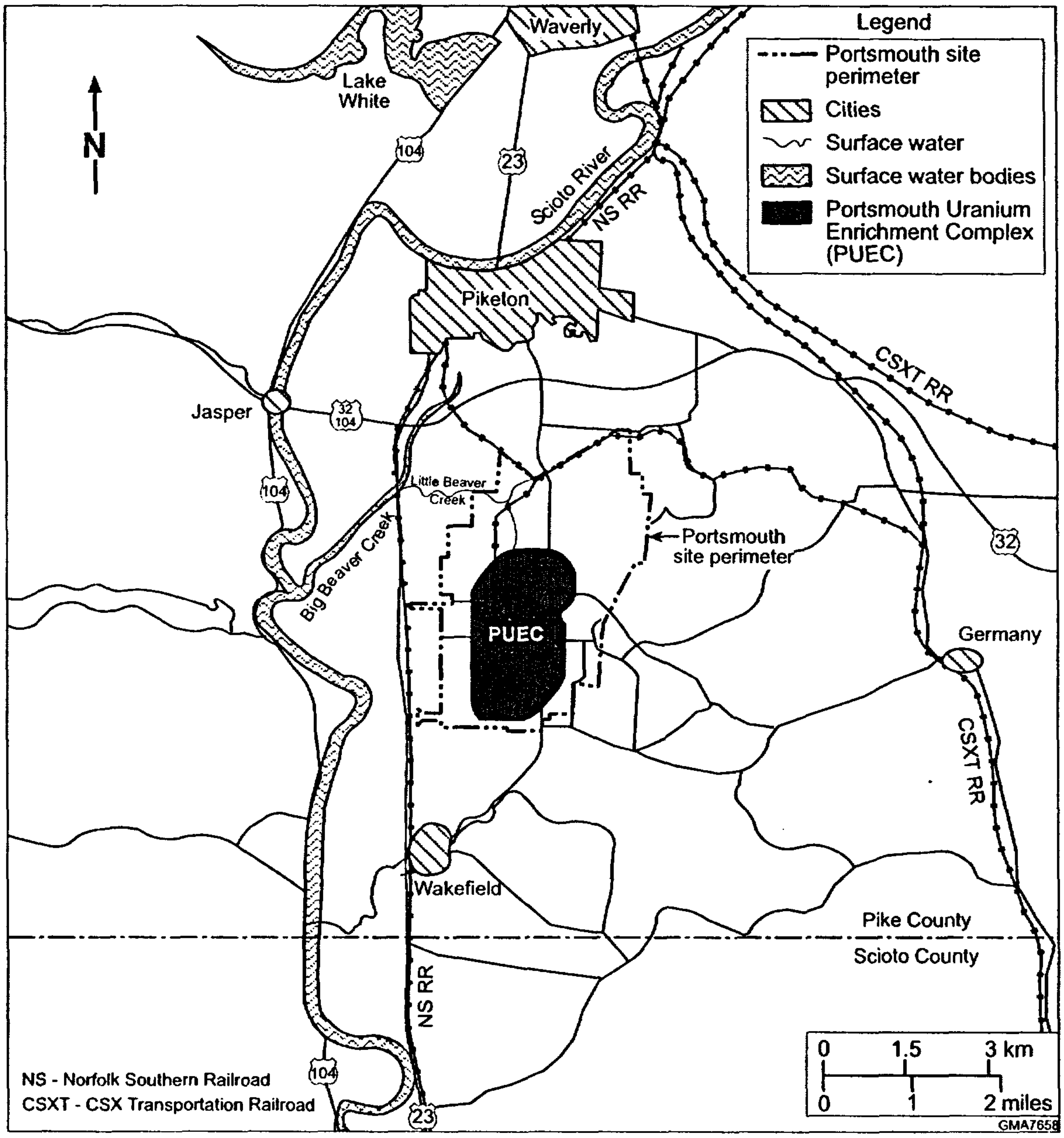

FIGURE 3.4 Regional Map of the Portsmouth Site Vicinity (Source: Adapted from LMES 1996b)

sitewide information from ongoing RCRA investigations is also included to put environmental conditions in the current cylinder storage areas into the context of sitewide conditions.

TABLE 3.6 Locations of DOE Depleted UF_6 Cylinders at the Portsmouth Site[a]

Yard	Area (ft^2)	Number of Cylinders
X-745-C	550,000	8,988
X-745-E	215,000	4,400

[a] Locations of cylinders as of May 1996.

Source: Cash (1996).

3.2.1 Cylinder Yards

The DOE-managed cylinders containing depleted UF_6 at the Portsmouth site are stored in two cylinder yards, X-745-C (C-yard) and X-745-E (E-yard) (Table 3.6; Figure 3.5). These storage yards have concrete bases. The cylinders are stacked two high to conserve yard storage space, with the cylinder-to-cylinder contact typically occurring in the areas of the stiffening rings. All 10- and 14-ton (9- and 12-metric ton) cylinders stored in these yards have been or are being inspected and repositioned. They are being placed on new concrete saddles with sufficient room between cylinders and cylinder rows to permit adequate visual inspection.

In addition to the DOE-generated cylinders, approximately 2,800 USEC-generated cylinders are stored in X-745-G yard (see Figure 3.5; DOE and USEC 1998a). These cylinders do not meet the 4-ft aisle spacing requirements; therefore, restacking of the cylinders is planned.

Two breached cylinders were identified in C-yard in June 1990; both breaches were attributed to handling damage and subsequent corrosion at the damaged point. One of the breached cylinders had a hole diameter of about 2 in. (5.1 cm); the estimated maximum material loss from this cylinder was 4 lb (1.8 kg). The cylinder contents were subsequently emptied into a new cylinder. The other cylinder had a much larger hole of approximately 9 in. × 18 in. (23 cm × 46 cm), with an estimated maximum material loss of about 109 lb (49 kg) (Barber et al. 1994). This cylinder was patched, and the contents were subsequently transferred to a new cylinder.

In March 1978, a cylinder containing liquid depleted UF_6 was accidentally dropped in the south-southwest portion of yard X-745-B (currently a USEC storage yard located north of Building X-330). Much of the material was carried into the storm sewer by melting snow. Cleanup efforts were conducted to collect as much of the lost material as possible; environmental sampling was also conducted to monitor uranium levels subsequent to the release (see Section 3.2.4).

3.2.2 Site Infrastructure

The Portsmouth site has direct access to major highway and rail systems, a nearby regional airport, and barge terminals on the Ohio River. Use of the Ohio River barge terminals requires transportation by public road from the Portsmouth site.

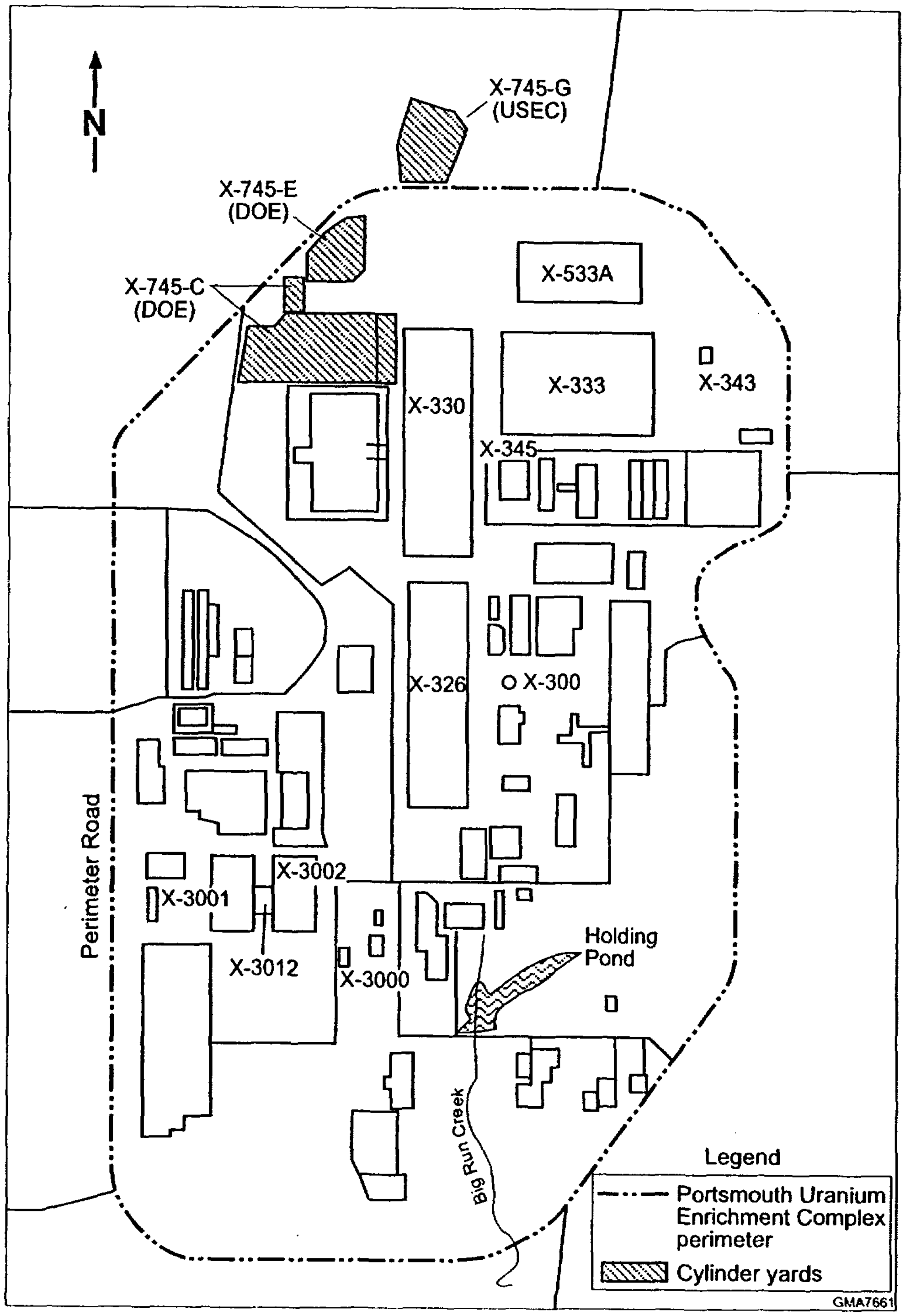

FIGURE 3.5 Locations of Cylinder Yards at the Portsmouth Site That Are Used to Store DOE-Managed Cylinders (Source: Adapted from DOE 1996g and MMES 1992a)

The Portsmouth site draws its water supply from an on-site facility consisting of four wells and from 31 off-site supply wells. Current water usage is about 14 million gal/d (53 million L/d). The maximum site capacity is 38 million gal/d (140 million L/d).

The Ohio Valley Electric Corporation supplies the site with electrical power. The current electrical consumption is 1,537 MW, with additional power supplied by a coal system using 4,500 tons per month. The maximum electrical design capacity is 2,260 MW, but a power supply of only 1,940 MW is guaranteed by the local power utility (MMES 1992b).

3.2.3 Ambient Air Quality and Airborne Emissions

The affected environment for air quality at the Portsmouth site is generally considered to be the EPA-defined AQCR. The EPA has designated the Portsmouth site as being in the Wilmington-Chillicothe-Logan AQCR in EPA Region 5. The EPA classifies Pike County, in which the Portsmouth site is located, as an attainment area for all six NAAQS criteria pollutants.

The State of Ohio has adopted ambient air quality standards for six criteria pollutants that specify maximum permissible short-term and long-term concentrations of these contaminants. These standards are listed in Table 3.7 and are generally the same as the national standards. In addition to standards for criteria pollutants, the Ohio Environmental Protection Agency has adopted emissions limits, guidelines, and acceptable ambient concentration levels for the 189 hazardous air pollutants specified in Section 112(b) of the *Clean Air Act Amendments* (CAAA). Regulations for these hazardous air pollutants are established in the NESHAPS (40 CFR Part 61).

Gaseous radiological emissions were monitored at one active source during 1996. The total discharge of uranium to the air from DOE sources at Portsmouth in 1996 was less than 0.01 Ci, a reduction of more than 90% compared with the 1994 total. The active source has been transferred to USEC responsibility, leaving DOE responsible for a single radiological source that is currently inactive (LMES 1997e).

Nonradiological emissions consisted mainly of fugitive dust. Other small sources of pollutants emitted chlorine, HF, methanol, assorted solvents, and coolants. The emission of the HAP trichloroethylene (TCE), several hundred gallons of which were collected in groundwater treatment facilities, was prevented by activated carbon filtration of the treatment facility air stripper off-gases (LMES 1997e).

TABLE 3.7 Ohio Ambient Air Quality Standards

Pollutant	Ohio Standard[a]	
	Primary	Secondary
Carbon monoxide (CO)		
1-hour average	35 ppm	35 ppm
8-hour average	9 ppm	9 ppm
Sulfur dioxide (SO_2)		
3-hour average	–[b]	0.50 ppm
24-hour average	0.14 ppm	–
Annual average	0.03 ppm	–
Particulate matter (PM_{10})		
24-hour average	150 $\mu g/m^3$	150 $\mu g/m^3$
Annual arithmetic mean	50 $\mu g/m^3$	50 $\mu g/m^3$
Ozone (O_3)		
1-hour average	0.12 ppm	0.12 ppm
Nitrogen dioxide (NO_2)		
Annual average	0.053 ppm	0.053 ppm
Lead (Pb)		
Quarterly average	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$
Gaseous fluorides (as HF)	NS[c]	NS[c]

[a] Annual standards are never to be exceeded; short-term standards are not to be exceeded more than once per year, unless noted.

[b] A hyphen (–) indicates no standard available for this averaging period.

[c] Ohio has no standard for gaseous fluorides.

Source: DOE (1996g).

3.2.4 Geology and Soil

3.2.4.1 Topography, Structure, and Seismic Risk

The topography of the Portsmouth site area consists of steep hills and narrow valleys, except where major rivers have formed broad floodplains. The site is underlain by bedrock of shale and sandstone.

The Portsmouth site is within 60 miles (96 km) of the Bryant Station-Hickman Creek Fault (ANL 1991b). No correlation has been made between this fault and historical seismicity. Seismic Source Zone 60 is a north-northeast-trending zone in central and eastern Ohio and includes the Portsmouth facility. For this site, the EBE was designated by DOE to have a return period of 250 years. A detailed analysis indicated that the peak ground motion for the EBE was approximately 0.06 times the acceleration of gravity (LMES 1997g). An earthquake of this size would have an equal probability of occurring any time during a 250-year period.

The seismic hazards at the Portsmouth site have been analyzed and documented in a SAR completed in March 1997 (see Sections 1.5 and 3.3 in LMES 1997g). The results presented in the SAR indicate that continued storage of depleted UF_6 cylinders at the Portsmouth site is safe. The results of the SAR analyses were used for the accident analyses in this PEIS (see Appendix C, Section C.4.2). A spectrum of accidents was considered, ranging from those having a high probability of occurrence but low consequences to those having high consequences but a low probability of occurrence. Natural phenomena accidents including earthquakes, floods, and tornadoes were among the accidents considered.

3.2.4.2 Soil

The substances in soil that might be associated with cylinder management activities at the Portsmouth site are uranium and fluoride compounds, which could be released if breached cylinders or faulty valves were present. In 1993, soil was sampled for radioactive parameters and chromium at 23 on-site, 32 off-site, and 4 background locations; soil sample analyses indicated no major environmental contamination (MMES 1994c). Analytical results for all off-site and most on-site sampling locations were similar to background values (MMES 1994d). One on-site sampling point (RIS-19, adjacent to the X-705 decontamination building) was contaminated with technetium-99 (143 pCi/g) and low levels of uranium (45 μg/g). This area is known to be contaminated from historical small spills; the source of uranium was not considered to be cylinder storage yards. Chromium concentrations were elevated at two locations immediately adjacent to and downwind of the X-633 cooling towers. Fluoride has not been analyzed in soil samples, but it is naturally occurring in soils and of low toxicity. Soils data have not been reported in more recent annual environmental reports (LMES 1996b, 1997e).

After the March 1978 cylinder handling accident (see Section 3.2.1), soil samples were collected to determine whether the X-745-C and X-745-B yards were contaminated (Geraghty & Miller 1994a-b). Total uranium concentrations in the X-745-C yard did not appear to be elevated, ranging from 2.2 to 4.4 mg/kg. Volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and PCBs were detected in shallow soil samples at maximum levels up to about 3 mg/kg (for polycyclic aromatic hydrocarbons [PAHs]). Although a few VOCs were detected at low concentrations in groundwater from one well, the source is unlikely to be the X-745-C yard (Geraghty & Miller 1994a).

Total uranium concentrations in the X-745-B yard were elevated in some soil samples, ranging from 2.7 to 352 mg/kg. The source of the uranium contamination might have been the 1978 spill. Some VOCs, SVOCs, and PCBs were also detected in shallow soil samples at maximum levels up to 31 mg/kg (for the PAH phenanthrene). However, no uranium, VOCs, SVOCs, or PCBs were detected in groundwater associated with the X-745-B yard. The contamination was confined to shallow soils and limited to the immediate proximity of the unit (Geraghty & Miller 1994b).

3.2.5 Water Resources

The affected environment for water resources consists of surface water within and in the vicinity of the site boundary and groundwater beneath the site. Analyses of surface water, stream sediment, and groundwater samples has indicated the presence of some contamination resulting from previous gaseous diffusion plant operations. Although several contaminants are present in the water, only small amounts of uranium and fluoride compounds are related to releases from the cylinders.

3.2.5.1 Surface Water

The Portsmouth site is drained by several small tributaries of the Scioto River (see Figure 3.4). The largest stream on the plant property is Little Beaver Creek, which drains the northern and northeastern portions of the site before discharging into Big Beaver Creek. Upstream of the plant, Little Beaver Creek flows intermittently during the year. On-site, it receives treated process wastewater from a holding pond (via the east drainage ditch) and storm-water runoff from the northwestern and northern sections of the plant via several storm sewers, watercourses, and the north holding pond. The average release to Little Beaver Creek for 1993 was 940 gpm (3,600 L/min).

All plant liquid effluents are regulated by an NPDES permit and are either discharged to Little Beaver Creek or piped directly to the Scioto River (Rogers et al. 1988b). The Portsmouth site has 21 NPDES-permitted outfalls, of which 9 required routine monitoring in 1993. The maximum annual average uranium concentration (0.024 mg/L) for 1993 was measured at NPDES outfall 003 on the west side of the site (MMES 1994c). Responsibility for all but two of these outfalls has been transferred to the USEC. The maximum uranium concentration in these two outfalls in 1996 sampling was 0.002 mg/L (LMES 1997d).

In addition to NPDES outfall monitoring, surface water bodies were monitored for radioactive and nonradioactive contamination at one on-site and nine off-site locations, which include upstream and downstream locations on the Scioto River. The surface water monitoring results for 1993 indicated that the measured radioactive contamination was consistently less than the applicable drinking water standards (MMES 1994d). In 1996, TCE was detected in one sampling round for Little Beaver Creek. The TCE levels returned to below detection limits by the fourth quarter of 1996, after an interceptor trench and pump were repaired (LMES 1997e).

In addition to surface water sampling, sediment sampling was performed twice in 1993 to monitor for potential radioactive contamination. The fall-quarter sediment sampling results indicated minor radioactive contamination in Little Beaver Creek sediments downstream of the east drainage ditch (MMES 1994d). Uranium was elevated only slightly at about 7 to 11 μg/g (MMES 1994c). Technetium-99 was present at an activity level of about 130 to 160 pCi/L in Little Beaver Creek below the site. No uranium contamination was detected in Big Beaver Creek downstream of the confluence with Little Beaver Creek; however, technetium-99 was measured at 23 pCi/g in the spring and 55 pCi/g in the fall. No radioactive contamination was detected in sediments from Big Run Creek or the Scioto River. Sediment data were not reported in more recent annual environmental reports (LMES 1996b, 1997e).

Results for 1993 for nonradioactive constituents indicated the presence of iron and zinc contamination in the streams (MMES 1994d). Fluoride and phosphate concentrations have also been monitored at upstream and downstream locations on the Scioto River. Results of this monitoring indicate no major difference between upstream and downstream concentrations of either chemical.

In addition, unusually high concentrations of thallium (up to about 400 mg/kg) were detected in Scioto River sediments in 1993 and 1994 (MMES 1994c; Manual 1998). These high measurements may have been due to an analytical laboratory problem (MMES 1994c). Levels at the same locations in 1995, 1996, and 1997 have been much lower, ranging from less than 3 to 19 mg/kg (Manual 1998).

3.2.5.2 Groundwater

Five hydrologic units at the Portsmouth site are important for groundwater flow and contaminant migration. These units are, in descending order, the Minford Clay, Gallia Sand, Sunbury Shale, Berea Sandstone, and Bedford Shale. The upper two units form an aquifer in unconsolidated deposits; the lower three units form a bedrock aquifer. At the site, the hydraulic conductivity (rate at which water moves) of all units is very low (Geraghty & Miller 1989a). The most conductive unit is the Gallia Sand, which has a mean hydraulic conductivity of 3.4 ft/d (0.0012 cm/s) and a range of 0.11 to 150 ft/d (0.000039 to 0.05 cm/s). This unit acts as the principal conduit for contaminant transport.

The direction of groundwater flow beneath the Portsmouth site is controlled by a complex interaction between the Gallia and Berea units (Geraghty & Miller 1989a). The flow patterns are also affected by the presence of storm sewers and the reduction in recharge caused by the presence of buildings and paved areas. Three main discharge areas exist for the groundwater system beneath the site: Little Beaver Creek to the north and east; Big Run Creek to the south; and two unnamed drainages to the west (Geraghty & Miller 1989a).

Although the Portsmouth site could use Scioto River water, all on-site water is currently supplied by wells. Four wells have the capacity to supply between 23.5 and 26 million gal/d (89 and 98 million L/d). Currently, about 14 million gal/d (53 million L/d) of groundwater is used for sanitary and production needs (ANL 1991b). Recharge of the aquifers is from river and stream flow, as well as from precipitation.

On-site groundwater at the Portsmouth site is monitored for radioactive and nonradioactive constituents at more than 245 wells. Additional off-site wells are used to monitor groundwater quality away from the site. On-site, three areas of groundwater contamination have been identified (Figure 3.6) that contain contaminants, including TCE, Freon-113, uranium, and technetium. In 1996, the maximum detected concentration of uranium was 26 μg/L for an on-site well in the X-701B holding pond area adjacent to Building X-333 (see Figure 3.6) (LMES 1997d).

3.2.6 Biotic Resources

3.2.6.1 Vegetation

The Portsmouth site within the perimeter road consists primarily of open grassy areas, including frequently mowed lawns, pasture, and old-field. Small areas of pine plantation, upland mixed hardwood forest, oak-hickory forest, bottomland mixed hardwood forest, and shrub thicket also occur on the site (DOE 1995c).

3.2.6.2 Wildlife

Habitats on the Portsmouth site support a relatively high diversity of terrestrial and aquatic wildlife species. Ground-nesting species include bobwhite and eastern box turtle. Various species of reptiles and amphibians are associated with streams and other surface water on the site. Migrating waterfowl use site retention ponds (ANL 1991b). Additional information on wildlife resources is available from MMES (1993) and ANL (1991b).

Little Beaver Creek, upstream of the site outfall, supports a high diversity of aquatic species. However, diversity is considerably lower downstream in Little Beaver Creek and in an unnamed stream (ANL 1991b).

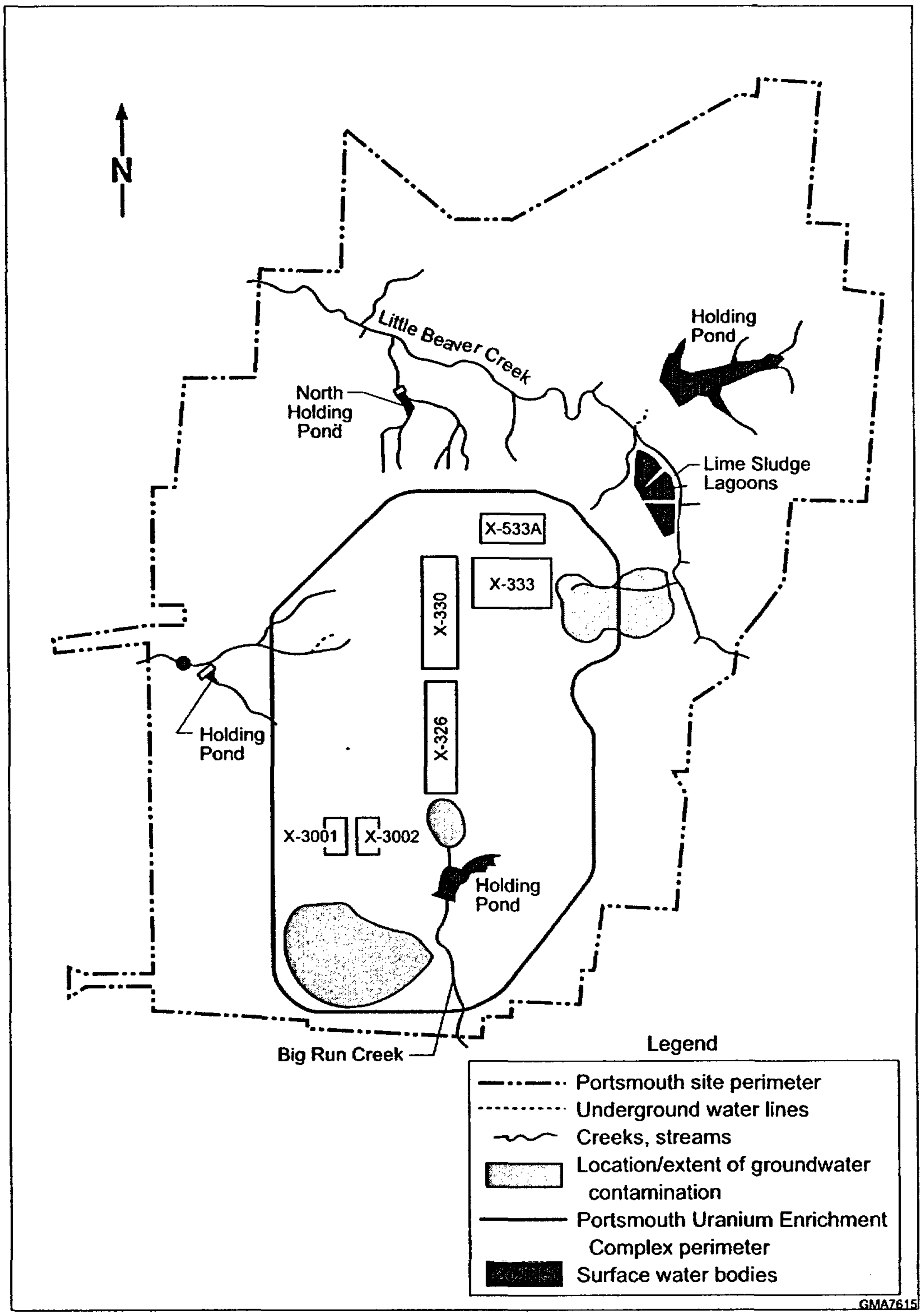

FIGURE 3.6 Locations of Contaminated Groundwater at the Portsmouth Site (Source: LMES 1996b)

3.2.6.3 Wetlands

A wetland survey of the Portsmouth site was conducted in 1995. Approximately 34 acres (13.8 ha) of wetlands occur on the site, excluding retention ponds. Forty-one wetlands meet the criteria for jurisdictional wetlands, while four wetlands are nonjurisdictional (Bechtel Jacobs Company LLC 1998). Wetlands on the site primarily support emergent vegetation that includes cattail, great bulrush, and rush. Palustrine forested wetlands occur on the site along Little Beaver Creek (ANL 1991b). The Ohio State Division of Natural Areas and Preserves has listed two wetland areas near the site as significant wetland communities: (1) a palustrine forested wetland, about 5 miles (8 km) east of the site, and (2) Givens Marsh, a palustrine wetland with persistent emergent vegetation, about 2.5 miles (4 km) northeast of the site.

3.2.6.4 Threatened and Endangered Species

No federal-listed plant or animal species are known to occur on the Portsmouth site. The Indiana bat, federal- and state-listed as endangered, has been reported in the site area and may occur on the site during spring or summer in breeding colonies. Roosting and nursery sites may include forested areas with loose barked trees (such as shagbark hickory) and standing dead trees (DOE 1995c).

The sharp-shinned hawk, listed by the State of Ohio as endangered, has been sighted occasionally at the Portsmouth site and has been observed foraging on the site (ANL 1991b). A population of long-beaked arrowhead, a wetland plant listed by the state as threatened, occurs just north of the site.

3.2.7 Public and Occupational Health and Safety

3.2.7.1 Radiation Environment

Operations at the Portsmouth site result in radiation exposures of on-site workers and members of the general public (Table 3.8). The total radiation dose to an off-site member of the public as a result of gaseous diffusion plant operations is estimated to be 0.07 mrem/yr, which is less than 0.02% of the average dose of 360 mrem/yr that an individual in the United States receives each year from natural background and medical sources of radiation.

Radiation exposures of the cylinder yard workers include exposures from activities performed outside the cylinder yards. The average dose ranged from 55 to 196 mrem/yr between 1990 and 1995 (Hodges 1996), considerably below the maximum dose limit of 5,000 mrem/yr set for workers (10 CFR Part 835).

TABLE 3.8 Estimated Radiation Doses to Members of the General Public and to Uranium Material Handlers at the Portsmouth Gaseous Diffusion Plant

Receptor	Radiation Source	Dose to Individual (mrem/yr)
Member of the general public (MEI)[a]	Routine site operations	
	Airborne radionuclides	0.016[b]
	Waterborne radionuclides	0.006[c]
	Direct gamma radiation	~0[d]
	Ingestion of foodstuffs	~0.044[e]
Uranium material handler[f]	External radiation	55 – 196[g]
Member of public or worker	Natural background radiation and medical sources	360[h]
DOE worker limit		2,000[i]

[a] The MEI was assumed to reside at an off-site location that would yield the largest dose. An average person would receive a radiation dose much less than the values shown in this table.

[b] Radiation doses from airborne releases were estimated using air concentrations calculated by an air dispersion model (LMES 1996b).

[c] The MEI was assumed to use the Scioto River as a source of drinking water and for fishing and recreation (LMES 1996b).

[d] Radiation levels around the site could result in doses about the same as those from off-site radiation levels (LMES 1996b).

[e] Radiation doses could result from consumption of locally produced foodstuffs (including fish caught in the Scioto River). Estimated doses were obtained by subtracting doses from airborne and waterborne radionuclides from the total dose (0.07 mrem/yr) received by the MEI (LMES 1996b).

[f] Uranium material handlers at the Portsmouth plant perform feed and withdrawal operations, cylinder movements, inspections, and radiation surveys (Hodges 1996).

[g] Range of annual average doses from years 1990 through 1995 (Hodges 1996).

[h] Average dose to a member of the U.S. population as estimated in Report No. 93 of the NCRP (1987b).

[i] DOE administrative procedures limit DOE workers to 2,000 mrem/yr (DOE 1992), whereas the regulatory dose limit for radiation workers is 5,000 mrem/yr (10 CFR Part 835).

3.2.7.2 Chemical Environment

The estimated hazard quotients for MEIs under existing environmental conditions near the Portsmouth site are listed in Table 3.9. These hazard quotients indicate that exposures to uranium, fluoride, and chromium for members of the general public near the Portsmouth site are much lower than those that might be associated with deleterious health effects. Portsmouth worker exposures are kept below the proposed OSHA permissible exposure limits (PELs) for uranium compounds and HF in the workplace (29 CFR Part 1910, Subpart Z, as of March 1998) (see Section 3.1.7.2).

3.2.8 Socioeconomics

The socioeconomic environment of the Portsmouth site was assessed in terms of regional economic activity, population and housing, and local public finances. The ROI consists of Jackson, Pike, Ross, and Scioto Counties in Ohio; 92.4% of employees at the site currently reside in these counties, with 46% residing in Scioto County (DOE 1996b). Allison and Folga (1997) provide a listing of the cities and school districts in each county within the ROI, together with supporting data for the socioeconomic characteristics described in this section.

3.2.8.1 Regional Economic Activity

Employment in the ROI rose relatively steadily between 1980 and 1995, growing from 75,600 to 81,000, an increase of 7.1%. Within the ROI, the largest percent employment increase occurred in Pike County (19.1%). Employment in the ROI is concentrated in Ross and Scioto Counties, which together had 71.1% of the ROI total in 1995. The BEA projects no overall increase in employment in the ROI over the period 1995 to 2020. However, Pike County (2.0%, 200 jobs) and Scioto County (0.4%, 100 jobs) are expected to gain in ROI employment, with losses expected elsewhere (BEA 1996b). Unemployment in the ROI in 1996 was 9.3% (Allison 1996). Employment at the Portsmouth site in 1995 was 2,400 (DOE 1997a), amounting to approximately 3.0% of total employment in the ROI.

Personal income in the ROI rose relatively steadily between 1980 and 1995, growing from $1.8 billion to $2.0 billion, an increase of 11%. The largest percent increase occurred in Pike County (41.7%). Personal income is concentrated in Ross and Scioto Counties, which together had 75.1% of total ROI personal income in 1995. The BEA projects a 26.8% increase in ROI personal income from 1995 to 2020 ($0.5 billion), with the largest increase in Pike County (38.2%, $0.09 billion) (BEA 1996b).

TABLE 3.9 Estimated Hazard Quotients for Members of the General Public near the Portsmouth Site under Existing Environmental Conditions[a]

Environmental Medium	Parameter	Assumed Exposure Concentration	Estimated Chronic Intake (mg/kg-d)	Reference Level[b] (mg/kg-d)	Hazard Quotient[c]
Air[d]	Uranium	< 0.01 $\mu g/m^3$	< 4.3×10^{-6}	0.0003	0.0095
	HF	< 0.11 $\mu g/m^3$	< 3.1×10^{-5}	0.02	0.0016
Soil[e]	Uranium	5.3 mg/kg	7.0×10^{-5}	0.003	0.024
	Chromium	23 mg/kg	3.0×10^{-4}	0.005	0.060
Surface water[f]	Uranium	24 µg/L	1.3×10^{-5}	0.003	0.0044
	Fluoride	600 µg/L	3.3×10^{-4}	0.06	0.0055
Sediments[f]	Uranium	11 mg/kg	3.0×10^{-6}	0.003	0.0010
Groundwater[g]	Uranium	26 µg/L	6.9×10^{-5}	0.003	0.25

[a] The receptor was assumed to be a long-term resident near the site boundary or other off-site monitoring location that would have the highest concentration of the contaminant being addressed; reasonable maximum exposure conditions were assumed. Only the exposure pathway contributing the most to intake levels was considered (i.e., inhalation for air and ingestion for soil, sediment, surface water, and groundwater). Residential exposure scenarios were assumed for air, soil, and groundwater analyses; recreational exposure scenarios were assumed for surface water and sediment analyses.

[b] The reference level is an estimate of the daily human exposure level that is likely to be without an appreciable risk of deleterious effects. The reference levels used in this assessment are defined in Appendix C.

[c] The hazard quotient is the ratio of the intake of the human receptor to the reference level. A hazard quotient of less than 1 indicates that adverse health effects resulting from exposure to that chemical alone are highly unlikely.

[d] Property-line sampling locations were used for assessment of general public exposures. Gross alpha was reported, which was used as a surrogate for uranium. Air exposure concentrations are the maximum annual average reported for all property-line and off-site monitoring locations (LMES 1996b).

[e] Soil exposure concentrations are the maximum values from 32 property-line and off-site sampling locations (MMES 1994c).

[f] Surface water and sediment exposure concentrations are the maximum annual averages reported for all NPDES outfall locations and other monitoring locations (MMES 1994c-d).

[g] Groundwater exposure concentration is the maximum concentration reported for on-site monitoring wells (LMES 1997d). These wells are not used for drinking water. Several additional substances exceeded drinking water standards or guidelines in 1996 (see Section 3.2.5.2); listed here are only substances of particular interest for this PEIS. Groundwater fluoride concentrations were not available.

3.2.8.2 Population

The ROI experienced small increases in population over the period 1980 to 1995, with total population growing from 202,900 to 205,200, an increase of 1.1%. The 1995 ROI population was concentrated in Ross and Scioto Counties (73.3%). The BEA projects the ROI population to increase by 9,800 (4.8%) from 1995 to 2020, with the largest increase in Pike County (7.7%, 1,900 people) (BEA 1996b).

3.2.8.3 Housing

Between 1980 and 1995, the number of housing units in the ROI increased 6.5%, from 75,800 to 80,800. Scioto and Ross Counties had 73.1% of the total housing units. Based on BEA (1996b) population forecasts for 1995 to 2020 and U.S. Bureau of the Census (1994) statistics, the number of vacant owner-occupied units in the ROI is expected to increase from 4,630 to 4,850 and the number of vacant rental units from 1,940 to 2,030.

3.2.8.4 Public Finance

The financial characteristics of local public jurisdictions included in the ROI are summarized in Table 3.10. Data are shown for the major revenue and expenditure categories and for the annual fiscal balance of the general fund account for cities, counties, and school districts.

3.2.9 Waste Management

The Portsmouth site generates several categories of waste, including wastewater, solid LLW, solid and liquid LLMW, nonradioactive hazardous waste, and nonradioactive nonhazardous solid waste. The site has an active program to minimize the generation of solid LLW, hazardous waste, and LLMW. Radioactive waste minimization efforts include segregating radioactive waste from nonradioactive waste; reduction of radiologically controlled areas, thereby reducing the use of disposable personal protective equipment; and improved segregation and handling of laboratory waste. Hazardous and mixed waste minimization actions include the sorting of burnable waste from radioactively contaminated materials, reduction of absorbent cloth use in PCB spill cleanup, reduction in floor sweeping waste, and substitution of materials containing nonhazardous components. Solid waste minimization actions include the recycling of corrugated cardboard and aluminum.

3.2.9.1 Wastewater

Wastewater at Portsmouth consists of nonradioactive sanitary and process-related wastewater streams, cooling water blowdown, radioactive process-related liquid effluent, discharges

TABLE 3.10 Summary of Financial Characteristics for the Portsmouth Site County, City, and School District Regions of Influence

Category	Finances[a] ($ million) ROI Counties	Finances[a] ($ million) ROI Cities	Category	Finances[a] ($ million) ROI School Districts
Revenues			**Revenues**	
Local sources	18.1	13.1	Local sources	22.8
Fines, fees, permits, etc.	3.3	3.2	State sources	33.6
Intergovernmental	3.7	4.1	Federal sources	4.6
Other	3.0	3.4	Other	0.2
Total	28.1	23.8	Total	61.2
Expenditures			**Expenditures**	
General government	12.1	6.7	Administration	0.0
Safety, health, community services	8.6	14.3	Instruction	36.9
			Services	23.4
Debt service	0.0	0.0	Physical plant	0.4
Other financing sources	7.6	2.5	Other	2.0
Total	28.3	23.6	Total	62.8
Revenues less Expenditures	-0.2	0.2	**Revenues less Expenditures**	-1.6

[a] Data for fiscal year ending December 31, 1994.

Sources: see Allison and Folga (1997).

from groundwater treatment systems, and storm-water runoff from plant areas, including runoff from the coal pile. Wastewater is processed at several on-site treatment facilities and is discharged to either the Scioto River or its immediate tributaries, including Little Beaver Creek, through 21 outfalls identified under the site NPDES permit. Treatment facilities include an activated sludge sewage treatment plant; several facilities that employ waste-specific pretreatment technologies (e.g., pH adjustment, activated carbon adsorption, metals removal, denitrification, and ion absorption); and numerous settling basins designed to facilitate solids settling, oil collection, and chlorine dissipation. In 1993, about 4.3 million gal/d (16 million L/d) of wastewater was discharged through the permitted outfalls. The site wastewater facilities are used at about 80% of a total capacity of approximately 5.3 million gal/d (20 million L/d) (DOE 1996g).

3.2.9.2 Solid Nonhazardous, Nonradioactive Waste

Solid waste — including sanitary refuse, cafeteria waste, industrial waste, disinfected medical waste (excluding drugs), and construction and demolition wastes — is collected and disposed of on-site at the X-735 sanitary landfill. Disposal is in shallow trenches covered with earthen fill. The site operates the landfill under an annual permit issued by Pike County, Ohio. No RCRA hazardous waste, PCB waste, or radioactive materials are allowed in the landfill. Asbestos waste is disposed of in specially designated areas of the sanitary landfill. In 1993, the landfill load was 236,000 yd^3 (180,000 m^3), which represented 86% of the landfill capacity of 273,000 yd^3 (209,000 m^3) (DOE 1996g).

Materials, such as certain construction and demolition debris, that are not regulated as solid waste by the state of Ohio are disposed of at the Portsmouth X-736 construction spoils area, located immediately west of the sanitary landfill.

3.2.9.3 Nonradioactive Hazardous and Toxic Waste

Nonradioactive waste that is considered hazardous waste according to RCRA or contains PCBs as defined under TSCA requires special handling, storage, and disposal. The Portsmouth site generates hazardous waste, including spent solvents and heavy-metal-contaminated waste, and PCB-contaminated toxic waste. As of 1994, Portsmouth had a RCRA Part B permit application pending before the Ohio Environmental Protection Agency. Portsmouth provides long-term on-site storage for hazardous waste at the X-7725 and X-326L RCRA container storage units. Several additional 90-day satellite storage areas are available for temporary storage of hazardous waste. In 1993, the site had 7,200 yd^3 (5,500 m^3) of hazardous waste in storage; site storage capacity is 9,700 yd^3 (7,400 m^3) (DOE 1996g).

Hazardous waste is sent to permitted off-site contractors for final treatment and/or disposal. Annual generation of solid hazardous waste ranged from 130 to 160 yd^3/yr (100 to 120 m^3/yr) in 1991 and 1992, respectively. Much of the hazardous waste load consists of PCB-contaminated waste. The site has over 2×10^6 lb (900,000 kg) of PCBs in various site electrical equipment in both active and inventory equipment (1993 data). In 1992, about 325 yd^3 (250 m^3) of hazardous organic liquid waste streams was sent to the K-25 site TSCA-approved incinerator. The capacity of the incinerator is 1,800 yd^3/yr (1,400 m^3/yr) (DOE 1996g).

3.2.9.4 Low-Level Waste

LLW generated at the Portsmouth site is stored on-site pending shipment to off-site treatment/disposal facilities. Portsmouth has initiated shipment of some LLW to the Hanford site (Washington) for disposal. Solid LLW generated at the site includes refuse, sludge, and debris contaminated with radionuclides, primarily uranium and technetium. As of 1995, 38,600 yd^3

(29,500 m³) of LLW was in storage at the Portsmouth site (DOE 1996g). The annual generation of LLW ranged from 2,920 yd³ (2,230 m³) in 1991 to 2,160 yd³ (1,650 m³) in 1992.

3.2.9.5 Low-Level Mixed Waste

LLW that contains PCBs or RCRA hazardous components is considered to be LLMW. All of the LLMW inventory at Portsmouth is subject to RCRA land disposal restrictions; LLMW is currently stored at the site. Treatment technologies exist for all of the LLMW streams in the Portsmouth inventory. As of 1995, 7,290 yd³ (5,570 m³) of mixed waste was in storage at the site. Of this, approximately 18% was derived from operations, and the rest was packaged solvent and/or metals-contaminated soil from environmental restoration activities. Mixed waste generation in 1992 was 510 yd³ (390 m³) liquid and 460 yd³ (350 m³) solid. In 1992, approximately 558,000 lb (254,000 kg) of organic liquid LLMW was sent to the TSCA incinerator or the K-25 site (DOE 1996g). In 1995 and 1996, approximately 1,300 yd³ (1,000 m³) of contaminated soil (LLMW) was shipped to a commercial facility in Utah for disposal.

3.2.10 Cultural Resources

An archaeological survey has been initiated at the Portsmouth site but has not been completed at this time. A survey conducted in 1952 recorded no sites. However, because of the archaeological site density in the surrounding area (over 200 sites have been recorded for Pike County alone), there is potential for discovering sites at Portsmouth using modern archaeological methods.

An inventory of historic buildings has been planned but has not been conducted at the Portsmouth site. It is likely that buildings related to uranium enrichment and atomic weapons manufacture would be eligible for the *National Register of Historic Places*. Two cemeteries, Holt Cemetery and Mount Gilead Cemetery, are located within the boundary of the facility.

No religious or sacred sites, burial sites, or resources significant to Native Americans have been identified at the Portsmouth site to date.

3.2.11 Minority and Low-Income Populations

The affected environment for assessing the potential for depleted UF_6 management activities to result in environmental justice impacts was based on data from the U.S. Bureau of the Census (1992a-b). The population residing within a 50-mile (80-km) radius of the Portsmouth site consists of 3.2% minorities and 20.7% persons with low income (see Appendix C, Section C.8.1).

3.3 K-25 SITE AT OAK RIDGE

The K-25 site is part of the Oak Ridge Reservation, which is located in Anderson and Roane Counties, Tennessee, approximately 25 miles (40 km) west of the city of Knoxville (Figure 3.7). The reservation consists of three major facilities — the K-25 site, Oak Ridge National Laboratory, and Y-12 plant (Figure 3.8) — and surrounding property. The 1,700-acre (688-ha) K-25 site contains the Oak Ridge Gaseous Diffusion Plant, which has been inactive since 1985. Currently, the primary mission of the K-25 site is environmental restoration and waste management activities (MMES 1994f).

Anderson County and the City of Oak Ridge have developed planning documents to control land use. Anderson County's comprehensive plan was created in 1982, and the City of Oak Ridge updated its comprehensive plan in 1988. Roane County has not formally developed or adopted a comprehensive or master plan.

The K-25 site includes more than 300 buildings with a combined floor space of 13 million ft^2 (1.2 million m^2) (MMES 1994f). Site management, in conjunction with DOE's land management policy, is currently pursuing an option to lease a 957-acre (387-ha) parcel of site land to the Community Reuse Organization of East Tennessee. The K-25 parcel, which is located

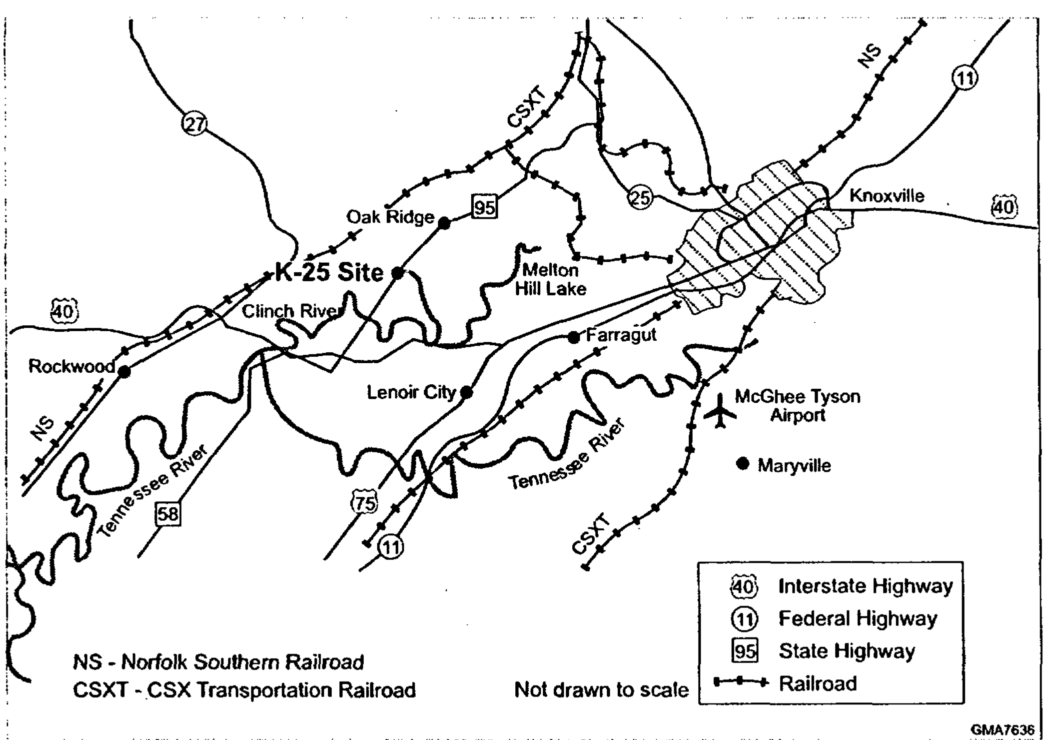

FIGURE 3.7 Regional Map of the K-25 Site Vicinity (Source: Adapted from ANL 1991c)

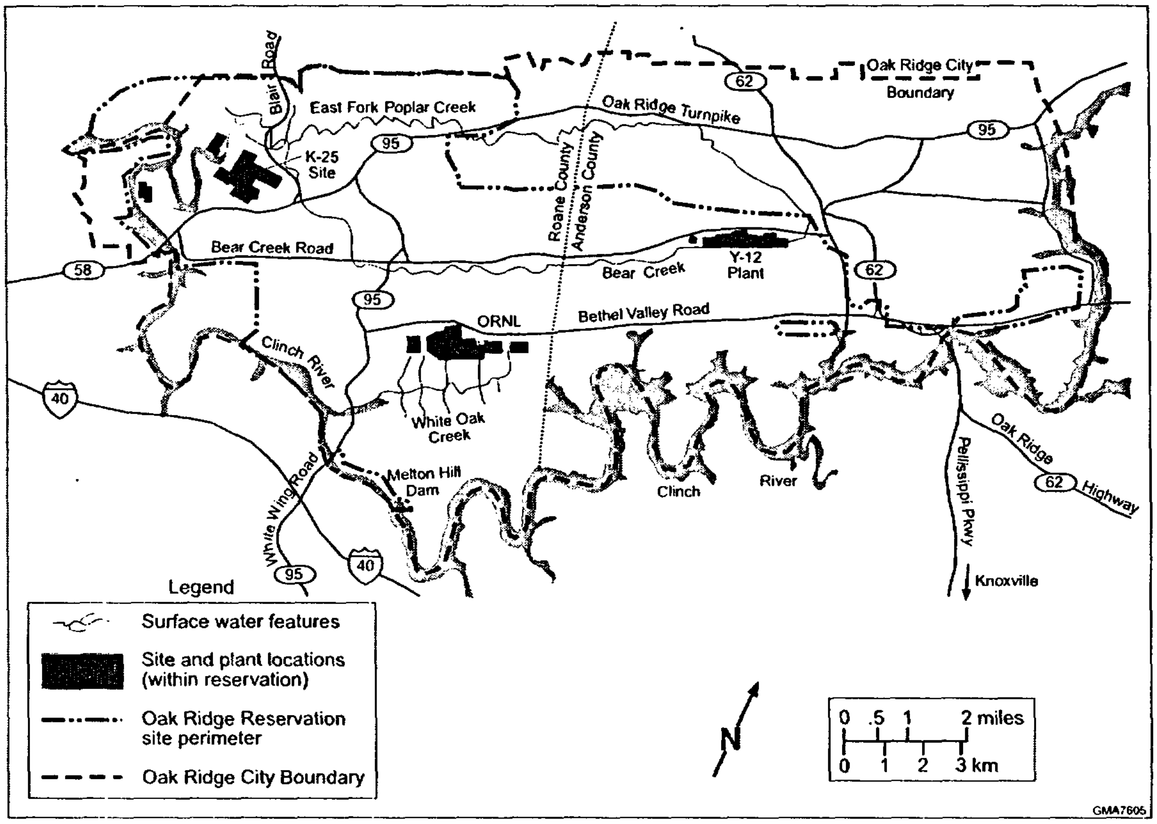

FIGURE 3.8 Map of the Oak Ridge Reservation (Source: MMES 1994f)

northeast of the core area, would be used as an industrial park, a use that is compatible with current site development plans. The Oak Ridge Reservation has a master plan that is updated every 5 years.

In 1989, the Oak Ridge Reservation was placed on the NPL, meaning that CERCLA cleanup requirements would be met in conducting remediation efforts. Several operable units (groups of similar potentially contaminated units) have been identified at the Y-12 plant, 20 waste area groupings (similar to operable units) have been identified at Oak Ridge National Laboratory, and 15 operable units have been identified at the K-25 site. Hazardous waste and mixed waste management at the Oak Ridge Reservation must also comply with RCRA regulations. The Oak Ridge Reservation FFA was developed to integrate CERCLA/RCRA requirements into a single remediation procedure. The discussion of affected environment in this PEIS focuses on conditions and contaminants pertinent to depleted UF_6 cylinder management. Some K-25 sitewide information from ongoing CERCLA/RCRA investigations is also included to put environmental conditions in the current depleted UF_6 cylinder storage areas into the context of sitewide conditions.

3.3.1 Cylinder Yards

There are 4,683 depleted UF_6 storage cylinders located in three K-25 site cylinder yards (Table 3.11; Figure 3.9). Cylinders are stacked two high to conserve storage yard space. The K-1066-K yard (K-yard) currently contains the most cylinders (2,945); it is constructed of concrete and crushed stone. Due to historical poor drainage conditions in K-yard, all cylinders in the K-yard are currently inspected annually. Most of the remaining K-25 site cylinders (1,716) are stored in the K-1066-E yard (E-yard), which is constructed of concrete; the K-1066-L yard (L-yard) contains only 22 cylinders. The E-yard and L-yard cylinders are inspected once every 4 years.

Four breached cylinders were discovered at the K-25 site in early 1992; two were located in K-yard and two in E-yard. The cause of the K-yard breaches seemed to be external corrosion from poor storage conditions, whereas the cause of the E-yard breaches could be attributed to handling damage and subsequent corrosion at the damaged points. The hole diameters for three of the breached cylinders ranged from 2 to 10 in. (5 to 25 cm); the dimensions of the fourth breach, the largest (an E-yard breached cylinder), were approximately 17 in. × 12 in. (43 cm × 30 cm). The four breached cylinders have been patched to restore their integrity, segregated from the other cylinders in K- and E-yards, and placed under temporary awnings. Because equipment to weigh the cylinders was not available at the K-25 site, the extent of material loss from these cylinders could not be determined.

One additional cylinder breach occurred in 1998 during the course of cylinder maintenance operations (i.e., surface preparation and painting). The breach was patched to prevent material loss from the cylinder.

3.3.2 Site Infrastructure

The K-25 site is located in an area with a well-established transportation network. The site is near two interstate highways, several U.S. and state highways, two major rail lines, and a regional airport (Figure 3.7).

Water is supplied to the K-25 site through a pumping station on the Clinch River. The water is treated and stored in two storage tanks. This system, with a capacity of 4 million gal/d (15 million L/d), also provides water to the Transportation Safeguards Facility and the K-25 site. Average water consumption for these three facilities in 1994 was 2 million gal/d (8 million L/d) (DOE 1995a).

Electric power is supplied by the Tennessee Valley Authority. The distribution of power is managed through the K-25 Power Operations Department. The average demand for electricity by all of the Oak Ridge DOE facilities, including the K-25 site, is approximately 100 MVa. The maximum capacity of the system is 920 MVa (DOE 1995a). Natural gas is supplied by the East Tennessee Natural Gas Company; the current daily capacity of 7,600 decatherms is capable of being increased, if necessary. The average daily usage in 1994 was 3,600 decatherms (DOE 1995a).

TABLE 3.11 Locations of DOE Depleted UF_6 Cylinders at the K-25 Site[a]

Yard	Area (ft^2)	Number of Cylinders
K-1066-K	134,825	2,945
K-1066-E	157,376	1,716
K-1066-L	43,824	22

[a] Locations of cylinders as of May 1996.

Source: Cash (1996).

3.3.3 Ambient Air Quality and Airborne Emissions

The affected environment for air quality at the K-25 site was generally considered to be the EPA-defined AQCR. The EPA has designated the K-25 site as being in the Eastern Tennessee-Southwestern Virginia Interstate AQCR in EPA Region 4. The EPA classifies this AQCR as an attainment area for all six NAAQS criteria pollutants.

The State of Tennessee has adopted NAAQS, which are presented in Table 3.12. In addition to the standards for criteria pollutants, the Tennessee Department of Environment and Conservation (TDEC) has adopted regulations to provide guidance for evaluating HAPs and air toxics that specify permissible short-term and long-term concentrations of various contaminants ("Hazardous Air Contaminants," *Air Pollution Control Regulations*, Chapter 11). The TDEC list is the same as the

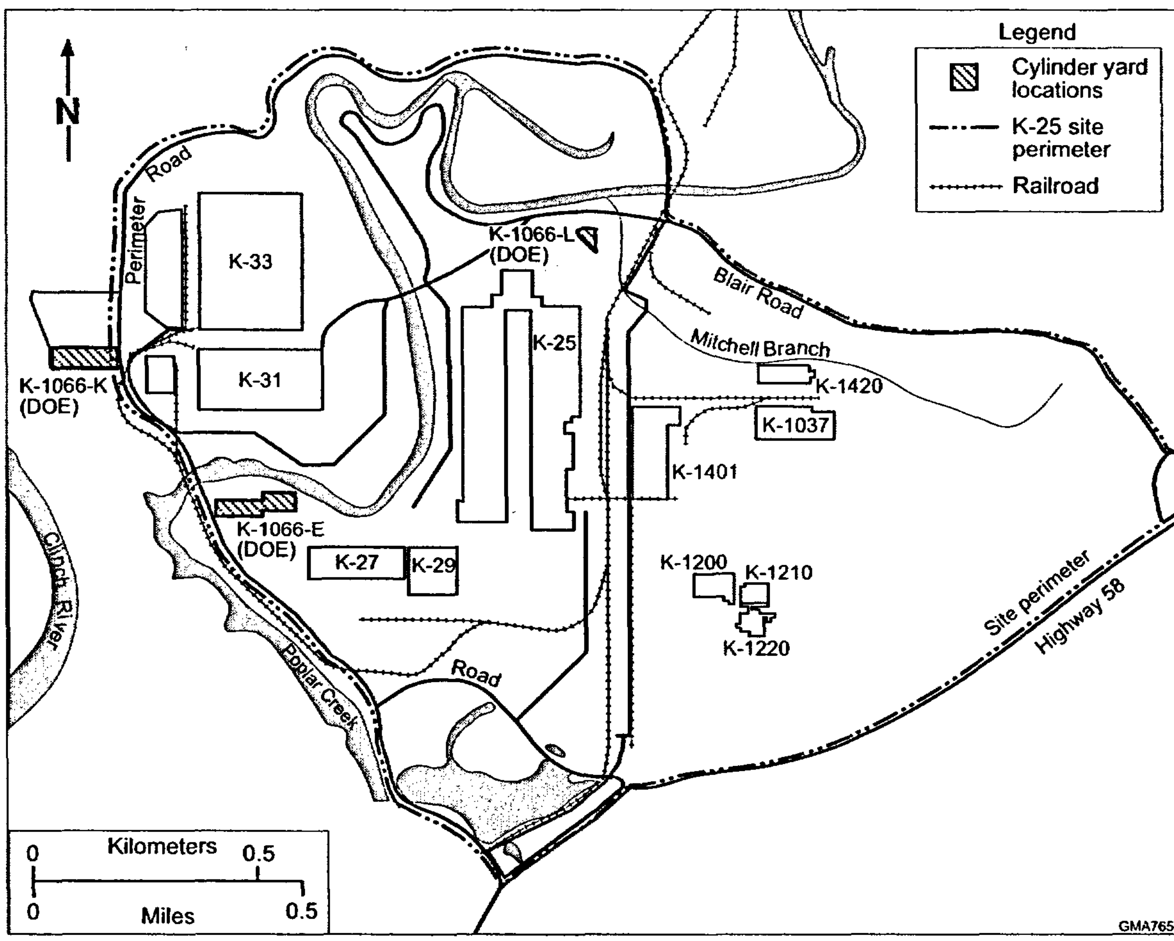

FIGURE 3.9 Locations of Cylinder Yards at the K-25 Site That Are Used to Store DOE Cylinders (Source: Adapted from MMES 1994a and LMES 1996c)

189 HAPs listed in Section 112(b) of the *Clean Air Act Amendments* (42 USC Parts 7401–7626). Emission standards for these HAPs are established in NESHAPS (40 CFR Part 61).

Ambient air quality is monitored in Anderson and Roane Counties by the Tennessee Division of Air Pollution Control. During 1992, no violations were recorded at the ozone monitor on the Oak Ridge Reservation or in nearby Nancy's Grove.

Although uranium enrichment activities at K-25 were discontinued in 1987, ambient air monitoring for uranium, PM_{10}, and several metals has continued at six on-site and off-site locations, with samples collected weekly; fluoride monitoring has been discontinued. As of 1996, monitoring was discontinued at four of the locations after review and concurrence by DOE and the Tennessee Department of Environmental Conservation (LMES 1997b).

For the period 1994 through 1996, the maximum annual average concentration of uranium for the six monitoring locations was 0.00039 $\mu g/m^3$ at Station K2 (LMES 1995a, 1996d, 1997b). The maximum annual average PM_{10} concentration for the same time period was 24.3 $\mu g/m^3$ (40% of the Tennessee and national primary and secondary standards); the maximum quarterly lead concentration was 0.0076 $\mu g/m^3$ (0.5% of the Tennessee and national primary and secondary standards) (LMES 1995a, 1996d, 1997b).

Steam plant emissions have accounted for most of the criteria pollutant emissions at the K-25 site (LMES 1995a). In 1994, all estimated emissions were less than the allowable ones. The K-25 site also contains a TSCA incinerator. Emissions from the incinerator are controlled by extensive exhaust-gas treatment. Estimated emissions from the incinerator are significantly less than the permitted allowable emissions.

TABLE 3.12 Tennessee Ambient Air Quality Standards

Pollutant	Tennessee Standard[a] Primary	Secondary
Carbon monoxide (CO)		
1-hour average	35.0 ppm	35.0 ppm
8-hour average	9.0 ppm	9.0 ppm
Sulfur dioxide (SO_2)		
3-hour average	–[b]	0.50 ppm
24-hour average	0.14 ppm	–
Annual arithmetic mean	0.03 ppm	–
Particulate matter (PM_{10})		
24-hour	150 µg/m^3	150 µg/m^3
Annual geometric mean	50 µg/m^3	50 µg/m^3
Ozone (O_3)		
1-hour average	0.12 ppm	0.12 ppm
Nitrogen dioxide (NO_2)		
Annual arithmetic mean	0.05 ppm	0.05 ppm
Lead (Pb)		
Quarterly average	1.5 µg/m^3	1.5 µg/m^3
Gaseous fluorides (as HF)		
12-hour average	4.5 ppb	4.5 ppb
24-hour average	3.5 ppb	3.5 ppb
7-day average	2.0 ppb	2.0 ppb
30-day average	1.5 ppb	1.5 ppb

[a] Annual standards are never to be exceeded; short-term standards are not to be exceeded more than once per year, unless noted.

[b] A hyphen (–) indicates no standard available for this averaging period.

Source: DOE (1996g).

3.3.4 Geology and Soil

3.3.4.1 Topography, Structure, and Seismic Risk

The topography of the K-25 site is varied; the maximum change in elevation across the site is about 420 ft (130 m). The site is underlain by sedimentary rocks composed of limestone and dolomite. Sinkholes, large springs, and other karst features can occur in the limestone formations adjacent to the site (DOE 1995a).

The most important structural feature near the site is a system of three faults: the Whiteoak Mountain Fault, which runs through the southeastern corner of K-25; the Kingston Fault, a parallel fault that occurs north of Poplar Creek; and the Copper Creek Fault, located in Melton Valley. A branch of the Whiteoak Mountain Fault originates just south of the site and runs due north through its center. None of these faults appear to have any topographic expression, and it is assumed that displacement took place prior to the development of the current surface of erosion (DOE 1979). Because no surface movement has occurred along these faults for more than 35,000 years and there has been no movement of a recurring nature within the past 500,000 years, the faults are not considered to be capable. Therefore, the evaluation-basis earthquake for this site was designated by DOE to have a return period of 1,000 years. For K-25, an earthquake that has a 1,000-year return period would have a horizontal top-of-soil acceleration of 0.2 times the acceleration of gravity. Such an earthquake could occur with equal probability any time during the 1,000-year period. For these conditions, slope stability and soil liquefaction (loss of shear strength) would not be problems, and rocking and rolling-out of cylinders would not occur for single or multiple-stacked cylinders (LMES 1997h).

The seismic hazards at the K-25 site have been analyzed and documented in a SAR completed in March 1997 (see Sections 1.5 and 3.4 in LMES 1997h). The results presented in the SAR indicate that continued storage of depleted UF_6 cylinders at the K-25 site is safe. The results of the SAR analyses were used for the accident analyses in this PEIS (see Appendix C, Section C.4.2). A spectrum of accidents was considered, ranging from those having a high probability of occurrence but low consequences to those having high consequences but a low probability of occurrence. Natural phenomena accidents including earthquakes, floods, and tornadoes were among the accidents considered.

3.3.4.2 Soil

Soil and groundwater data have been collected to determine whether contamination is associated with the K-25 cylinder yards (DOE 1994a). Substances in soil possibly associated with cylinder management activities are uranium and fluoride compounds, which could be released to soil if breached cylinders or faulty valves were present. In 1991, 122 systematic soil samples were collected at the K-yard; these samples had maximum concentrations of 0.14 mg/kg uranium-235 and

13 mg/kg uranium-238. Soil samples collected in March 1992 at the K-yard had a maximum uranium concentration of 36 ± 2 mg/kg.

In 1994, 200 systematic and 28 biased soil samples were collected in areas surrounding the cylinder yards; the maximum concentrations detected in these samples were 0.83 mg/kg uranium-235 at K-1066-F yard (F-yard) and 75 mg/kg uranium-238 at E-yard. Groundwater concentrations of total uranium (measured as gross alpha and gross beta) for upgradient and downgradient wells have indicated that although some elevated levels of uranium have been detected in cylinder yard soil, no migration to groundwater has occurred (DOE 1994a). The cause of the isolated elevated uranium-238 level in soil was not identified.

Soil samples collected as part of general site monitoring at K-25 and the immediate surrounding area in 1994 had the following maximum concentrations: uranium, 6.7 mg/kg; Aroclor 1254 (a PCB), 0.16 mg/kg; cadmium, 0.34 mg/kg; mercury, 0.15 mg/kg; and nickel, 33 mg/kg (LMES 1996c). Fluoride was not analyzed in the soil samples, but it is naturally occurring and of low toxicity. Concentrations of uranium in 1995 and 1996 soil monitoring were lower (LMES 1996d, 1997b).

As part of ongoing CERCLA/RCRA investigations for the K-25 site, several areas of soil have been identified as contaminated with radionuclides and/or chemicals. However, this contamination is not associated with the depleted UF_6 cylinder yards, and remediation is being implemented as a part of ongoing CERCLA/RCRA activities at the site.

3.3.5 Water Resources

The affected environment for water resources consists of surface water within and in the vicinity of the site boundary and groundwater beneath the site. Analyses of surface water, stream sediment, and groundwater samples has indicated the presence of some contamination resulting from previous gaseous diffusion plant operations. Although several contaminants are present in the water, only small amounts of uranium and fluoride compounds are related to releases from the cylinders.

3.3.5.1 Surface Water

The K-25 site is located near the confluence of the Clinch River (a tributary of the Tennessee River) and Poplar Creek (Figure 3.10). There are effluent discharge points on both Poplar Creek and the Clinch River and two water withdrawal points on the Clinch River (DOE 1979).

Because of the presence of the Melton Hill and Watts Bar Dams, the hydrology of the Clinch River-Poplar Creek system near K-25 is very complex. In the vicinity of K-25, most of the facilities are free of flood hazards for both the 100-year and 500-year maximum probable floods in Poplar Creek (Rothschild et al. 1984).

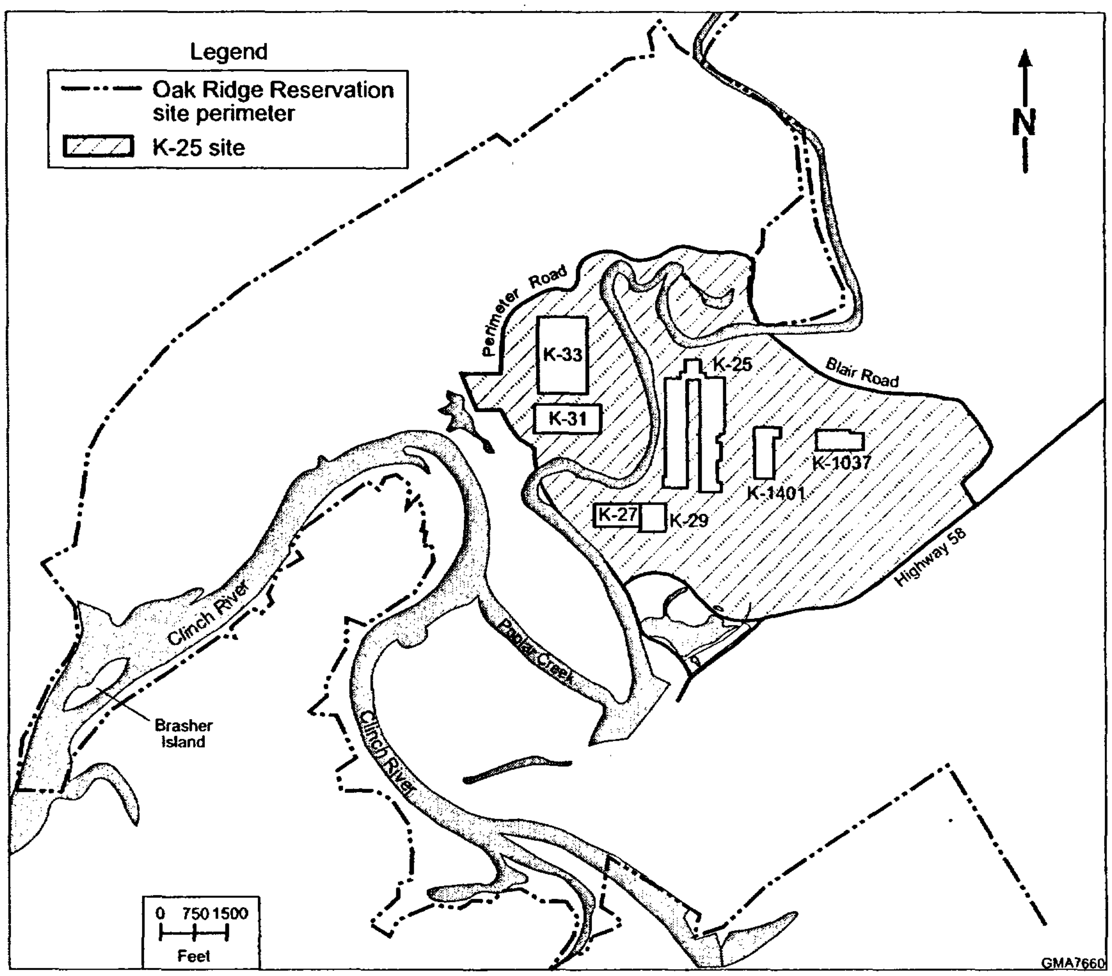

FIGURE 3.10 Locations of Surface Water Bodies near the K-25 Site

As of 1996, surface water monitoring at K-25 has been conducted at five locations (LMES 1997b). The K-1710 sampling location provides information on surface water conditions upstream of K-25. Station K-716 is downstream of most of the K-25 operations and provides information on the cumulative effects of K-25 operations. The remaining sampling locations are at points where drainage in the major surface water basins converge before discharging to Poplar Creek.

Samples from the K-25 site are analyzed monthly for radionuclides; quarterly samples are collected and analyzed for general water quality parameters, selected metals, and organic compounds (LMES 1997b). Uranium levels have been considerably below permitted levels based on radiological standards. In most instances, results for nonradiological parameters are considerably below their applicable Tennessee water quality standards. In 1994, zinc, which occurs naturally in the soils of the area, was detected just above the limit in one sample from the K-1700 sampling location (LMES

1995a). Lead, nickel, and mercury were occasionally detected but always at low concentrations. In general, analytical results for samples collected upstream of K-25 are chemically similar to those collected downstream of the site.

Sediment sampling has also been performed at points that coincide with the K-25 water sampling locations. These samples were analyzed for uranium and other parameters. For 1994, the following maximum concentrations were measured: uranium, 43 μg/g; mercury, 6 μg/g; nickel, 89 μg/g; and Aroclor 1254, 10 μg/g (LMES 1996c).

3.3.5.2 Groundwater

Groundwater in the vicinity of the K-25 site occurs in a surficial aquifer and in bedrock aquifers. The surficial aquifer is made up of man-made fill, alluvium, and the residuum of weathered bedrock (Geraghty & Miller 1989b). The depth to unweathered bedrock varies from less than 10 ft (3 m) to more than 50 ft (15 m), depending on the characteristics of the underlying rocks. Bedrock aquifers in the area are composed of sandstones, siltstones, shales, dolostones, and limestones. The uppermost bedrock aquifer occurs in the Chickamauga Group. Shale beds restrict groundwater flow in the aquifer, resulting in concentrated flow along the limestone-shale contact, with resultant solution cavities. The next lower aquifer occurs in the Knox Group, which is composed of dolostone with interbeds of limestone. Solution features such as sinkholes and caverns are common and are an important route for groundwater flow. This unit is the principal aquifer on the K-25 site (Rothschild et al. 1984).

In 1994 and 1995, groundwater samples were collected from a network of between 200 and 225 monitoring wells at the K-25 site (LMES 1995a, 1996d). The number of wells monitored was greatly decreased in 1996, based on reorganization of the site into six watersheds and reduced monitoring requirements (LMES 1997b). In the 1994 and 1995 sampling conducted for the larger network of monitoring wells, the following substances were detected at levels exceeding their associated primary drinking water standards: antimony, arsenic, barium, cadmium, chromium (up to 0.741 mg/L), fluoride (only at 2 wells), lead, nickel (up to 0.626 mg/L), thallium (up to 0.021 mg/L), benzene (up to 6 μg/L), carbon tetrachloride, 1,1-dichloroethene (greater than 1,000 μg/L), chloroform, 1,2 dichloroethene (greater than 1,000 μg/L), methylene chloride, toluene (greater than 1,000 μg/L), 1,1,2-trichloro-1,2,2-trifluoroethane (greater than 1,000 μg/L), trichloroethylene (up to 11,000 μg/L), 1,1,1-trichloroethane (up to 140,000 μg/L), 1,1,2-trichlororethane, tetrachloroethene (up to 17 μg/L), vinyl chloride, gross alpha activity (up to 43 pCi/L), and gross beta activity (up to 6,770 pCi/L) (LMES 1995a, 1996d). Aluminum, iron, and manganese also consistently exceeded secondary, non-health-based standards because of the natural geochemical nature of the groundwater underlying the site (LMES 1996d).

Exit-pathway groundwater surveillance monitoring was also conducted in 1994 and 1995 at convergence points where shallow groundwater flows from relatively large areas of the K-25 site and converges before discharging to surface water locations (LMES 1995a, 1996d). The exit pathway monitoring data are representative of maximum groundwater contamination levels associated with the K-25 site to which the general public might possibly have access in the future. For 1994, monitoring indicated that thallium, bis(2-ethylhexyl)phthalate, and trichloroethylene were present in at least one exit pathway well sample at concentrations exceeding primary drinking water standards (LMES 1996c). The following average concentrations of these constituents were measured: thallium, 0.007 mg/L; bis(2-ethylhexyl)phthalate, 0.169 mg/L; and trichloroethylene, 0.008 mg/L. Alpha activity and fluoride levels were also measured but did not exceed reference levels (average concentration was 4.4 pCi/L for alpha activity and 0.4 mg/L for fluoride). For 1995, monitoring indicated that no inorganic or organic substances exceeded primary drinking water standards, but alpha activity exceeded the reference level in one well during the spring sampling event only (level of 17 pCi/L) (LMES 1996d).

3.3.6 Biotic Resources

3.3.6.1 Vegetation

About 65% of the land within a 5-mile (8-km) radius of the K-25 site is forested, although most of the K-25 site consists of mowed grasses. Oak-hickory forest is the predominant community on ridges and dry slopes. Mixed pine forests or pine plantations, many of which are managed, have replaced former agricultural fields. Selective logging occurred over much of the site prior to 1986. Cedar barrens are small communities, primarily on shallow limestone soils, which support drought-tolerant species such as little bluestem, dropseed, eastern red cedar, and stunted oak. A cedar barrens across the Clinch River from the K-25 site may be the best example of this habitat in the state and has been designated a State Natural Area.

3.3.6.2 Wildlife

The high diversity of habitats in the area supports a large number of wildlife species. Ground-nesting species commonly occurring on the K-25 site include the red fox, ruffed grouse, and eastern box turtle. Canada geese are also common in the K-25 area, and most are probably residents (ANL 1991c). Waterfowl, wading birds, and shorebirds are numerous along the Clinch River in its backwaters and in ponds. Two great blue heron rookeries are located north of the K-25 site on Poplar Creek (ANL 1991c). Species commonly associated with streams and ponds include the muskrat, beaver, and several species of turtles and frogs.

The aquatic communities within the Clinch River and Poplar Creek support a high diversity of fish species and other aquatic fauna. Mitchell Branch supports fewer fish species, although the diversity of fish species increased considerably downstream of most K-25 discharges between 1989 and 1995 (LMES 1995a).

3.3.6.3 Wetlands

Numerous wetlands occur in the vicinity of K-25, including three small wetlands along Mitchell Branch (ANL 1991c). Extensive forested wetlands occur along Poplar Creek, East Fork Poplar Creek, Bear Creek, and their tributaries. Shallow water embayments of Melton Hill Reservoir and Watts Bar Reservoir support large areas of palustrine emergent wetlands with persistent vegetation. Forested wetlands occur along these marshy areas and extend into tributaries (DOE 1995a).

3.3.6.4 Threatened and Endangered Species

No federal listed threatened or endangered species are known to occur on the K-25 site. Bachman's sparrow, state-listed as endangered, nests on the Oak Ridge Reservation. Suitable habitat on the reservation includes open pine woods with shrubs and dense ground cover (ANL 1991c). Sharp-shinned hawk and Cooper's hawk, both listed by the state as endangered, forage on the Oak Ridge Reservation. The purple fringeless orchid, state-listed as threatened, occurs in a wetland near the south boundary of the K-25 site and in several areas along Bear Creek and its tributaries southeast of K-25.

3.3.7 Public and Occupational Health and Safety

3.3.7.1 Radiation Environment

Radiation doses to the K-25 cylinder yard workers and to off-site members of the general public are summarized in Table 3.13. Airborne emissions from operations of the K-25 site constitute a small fraction of the emissions from the entire Oak Ridge Reservation and result in approximately 10 times less exposure of the off-site general public than do emissions from the entire reservation. The total radiation dose to the off-site MEI of the general public is estimated to be about 4.5 mrem/yr (LMES 1997b). This dose is much less than the maximum dose limit of 100 mrem/yr set for the general public (DOE Order 5400.5) and a small fraction of the dose from natural background and medical sources of radiation.

Between 1991 and 1995, the average annual dose to cylinder yard workers ranged from 32 to 92 mrem/yr, which is less than 2% of the maximum radiation dose limit of 5,000 mrem/yr set for radiation workers (10 CFR Part 835).

TABLE 3.13 Estimated Radiation Doses to Members of the General Public and to Cylinder Yard Workers at the K-25 Site

Receptor	Radiation Source	Dose to Individual (mrem/yr)
Member of the general public (MEI)[a]	Routine site operations	
	Airborne radionuclides[b]	
	K-25 site only	0.056
	Entire Oak Ridge Reservation	0.45
	Waterborne radionuclides[c]	1.52
	Direct gamma radiation	1[d]
	Ingestion of wildlife	1.58[e]
Cylinder yard worker	External radiation	32 – 92[f]
Member of public or worker	Natural background radiation and medical sources	360[g]
DOE worker limit		2,000[h]

[a] The MEI was assumed to reside at an off-site location that would yield the largest dose. An average person would receive a radiation dose much less than the values shown in this table.

[b] Radiation doses from airborne releases were estimated using an air dispersion model and considered exposures from external radiation, inhalation, and ingestion of foodstuffs. Doses were estimated on the basis of the emission rate from the K-25 site only and from the entire Oak Ridge Reservation (LMES 1997b).

[c] Radiation doses would result from drinking 730 L of water per year provided by the Kingston Municipal Water Plant (0.32 mrem/yr) and ingesting 21 kg of the maximally contaminated fish caught from lower Poplar Creek per year (1.2 mrem/yr) (LMES 1997b).

[d] Radiation doses would result from 250 hours of shoreline activity per year along the banks of Poplar Creek or Clinch River (LMES 1997b).

[e] Radiation doses would result from ingestion of two deer containing the field-derived concentration of cesium-137 (1.5 mrem/yr) and ingestion of eight Canada geese per year with an average cesium-137 concentration of 0.12 pCi/g (0.08 mrem/yr) (LMES 1997b).

[f] Range of annual average doses from years 1991 through 1995 (Hodges 1996).

[g] Average dose to a member of the U.S. population as estimated in Report No. 93 of the NCRP (1987b).

[h] DOE administrative procedures limit DOE workers to 2,000 mrem/yr (DOE 1992), whereas the regulatory dose limit for radiation workers is 5,000 mrem/yr (10 CFR Part 835).

3.3.7.2 Chemical Environment

The estimated hazard quotients for members of the general public under existing environmental conditions near the K-25 site are listed in Table 3.14. The estimated hazard quotients indicate that exposures to uranium compounds, fluoride compounds, and other contaminants near the K-25 site are generally lower than those that might be associated with deleterious health effects (hazard quotient less than 1). An exception is groundwater, where hazard quotients for several substances could exceed the threshold of 1. However, it is highly unlikely that this groundwater will be used as a drinking water source.

Oak Ridge worker exposures are kept below the proposed OSHA PELs for uranium compounds and HF in the workplace (29 CFR Part 1910, Subpart Z, as of March 1998) (see Section 3.1.7.2).

3.3.8 Socioeconomics

The socioeconomic environment of the Oak Ridge K-25 site was assessed in terms of regional economic activity, population and housing, and local public finances. The ROI consists of Anderson, Knox, Loudon, and Roane Counties in Tennessee; 91.3% of employees at the site currently reside in these counties, with 36% residing in Knox County and 33.3% in Anderson County (DOE 1997a). Allison and Folga (1997) provide a list of the cities and school districts in each county within the ROI, together with supporting data for the socioeconomic characteristics described in this section.

3.3.8.1 Regional Economic Activity

Employment in the ROI rose relatively steadily between 1980 and 1995, growing from 242,600 to 311,700, an increase of 28.5%. Within the ROI, the largest percent employment increase occurred in Knox County (31.9%), which had 74.6% of total ROI employment in 1995. The BEA projects a 9.4% increase in employment in the ROI over the period 1995 to 2020 (29,400 jobs), with the largest increase expected to occur in Knox County (10.2%, 23,700 jobs) (BEA 1996c). Unemployment in the ROI in 1996 was 3.7% (Allison 1996). Employment at the site in 1995 was 21,500 (DOE 1996e), amounting to approximately 4.3% of total employment in the ROI.

Personal income in the ROI rose relatively steadily between 1980 and 1995, growing from $4.7 billion to $6.7 billion, an increase of 43%. The largest percent increase occurred in Knox County (48.7%), which had 72.3% of total ROI personal income in 1995. The BEA projects a 40.7% increase in ROI personal income from 1995 to 2020 ($2.7 billion), with the largest increase in Knox County (41.8%, $2.0 billion) (BEA 1996c).

TABLE 3.14 Estimated Hazard Quotients for Members of the General Public near the K-25 Site under Existing Environmental Conditions[a]

Environmental Medium	Parameter	Assumed Exposure Concentration	Estimated Chronic Intake (mg/kg-d)	Reference Level[b] (mg/kg-d)	Hazard Quotient[c]
Air[d,e]	Uranium	0.0004 µg/m³	1.1×10^{-7}	0.0003	0.0004
Soil[d]	Uranium	6.7 µg/g	8.9×10^{-5}	0.003	0.03
	Cadmium	0.34 µg/g	4.5×10^{-6}	0.001	0.0045
	Mercury	0.15 µg/g	2.0×10^{-6}	0.0003	0.0067
	Nickel	33 µg/g	4.4×10^{-4}	0.02	0.022
	Aroclor 1254	0.16 µg/g	2.1×10^{-6}	0.00002	0.11
	Aroclor 1254[f]	0.16 µg/g	9.1×10^{-7}	2.0 (slope factor)	1.8×10^{-6} (cancer risk)
Surface water[d]	Uranium	13 µg/L	7.1×10^{-6}	0.003	0.0024
	Fluoride	180 µg/L	9.9×10^{-5}	0.06	0.0016
Sediments[d]	Uranium	43 µg/g	1.2×10^{-5}	0.003	0.0039
	Cadmium	0.38 µg/g	1.0×10^{-7}	0.001	0.0001
	Mercury	6 µg/g	1.6×10^{-6}	0.0003	0.0055
	Nickel	89 µg/g	2.4×10^{-5}	0.02	0.0012
	Aroclor 1254	10 µg/g	2.7×10^{-6}	0.00002	0.14
	Aroclor 1254[f]	10 µg/g	3.9×10^{-7}	2.0 (slope factor)	7.8×10^{-7} (cancer risk)
Groundwater[g]	Uranium	25 µg/L	1.8×10^{-4}	0.003	0.24
	Fluoride	4,000 µg/L	1.1×10^{-2}	0.06	1.9

[a] The receptor was assumed to be a long-term resident near the site boundary or other off-site monitoring location that would have the highest concentration of the contaminant being addressed; reasonable maximum exposure conditions were assumed. Only the exposure pathway contributing the most to intake levels was considered (i.e., inhalation for air and ingestion for soil, sediment, surface water, and groundwater). Residential exposure scenarios were assumed for air, soil, and groundwater analyses; recreational exposure scenarios were assumed for surface water and sediment analyses.

[b] The reference level is an estimate of the daily human exposure level that is likely to be without an appreciable risk of deleterious effects. The reference levels used in this assessment are defined in Appendix C. For carcinogens, the slope factor is also given; slope factors in units of $(mg/kg\text{-}d)^{-1}$ are multiplied by lifetime average intake to estimate excess cancer risk.

[c] The hazard quotient is the ratio of the intake of the human receptor to the reference does. A hazard quotient of less than 1 indicates that adverse health effects resulting from exposure to that chemical alone are highly unlikely. For carcinogens, the cancer risk (intake × slope factor) is also given. Increased cancer risks between 10^{-6} and 10^{-4} are considered tolerable at hazardous waste sites; risks less than 10^{-6} are considered negligible.

[d] Exposure concentrations are the maximum annual averages for all monitoring locations (LMES 1995a, 1996c).

[e] HF was not measured.

[f] Parameters analyzed for carcinogenic effects; all other parameters were analyzed for noncarcinogenic effects.

[g] Concentration for uranium is the maximum annual average for all exit pathway monitoring locations because these are the locations where the general public could most likely be exposed in the future. Alpha activity was used as a surrogate measure of uranium concentration. The well-specific concentration for fluoride was not available; the exposure concentration given is actually the drinking water standard. The hazard index for fluoride could therefore exceed that presented. Several additional substances exceeded drinking water standards or guidelines in 1994 and 1995 monitoring; listed here are only substances of particular interest for this PEIS. Data are from LMES (1996c,d).

3.3.8.2 Population

The ROI experienced small increases in population over the period 1980 to 1995, with total population growing from 464,000 to 506,600, an increase of 9.2%. The 1995 ROI population was concentrated in Knox County (69.8%). The BEA projects the ROI population as a whole to increase by 77,200 (15.2%) from 1995 to 2020, with the largest increase in Knox County (15.9%, 56,300 people) (BEA 1996c).

3.3.8.3 Housing

Between 1980 and 1995, the number of housing units in the ROI increased 13.8%, from 181,300 to 206,200. Knox County had 69.6% of the total housing units. Based on BEA (1996c) population forecasts for 1995 to 2020 and U.S. Bureau of the Census (1994) statistics, the number of vacant owner-occupied units in the ROI is expected to increase from 10,190 to 11,750 and the number of vacant rental units from 5,030 to 5,800.

3.3.8.4 Public Finance

The financial characteristics of local public jurisdictions included in the ROI are summarized in Table 3.15. Data are shown for the major revenue and expenditure categories and for the annual fiscal balance of the general fund account for cities, counties, and school districts.

3.3.9 Waste Management

The K-25 site generates industrial and sanitary waste, including wastewater, solid non-hazardous waste, solid and liquid hazardous waste, and radioactive waste. Much of the waste generated at K-25 is by-products of the ongoing environmental remediation efforts at the site. The K-25 site has the capability to treat wastewater and certain radioactive and hazardous waste; other waste treatment facilities that can process and/or dispose of K-25 waste are located at the Y-12 Plant and Oak Ridge National Laboratory. The K-25 waste facilities also store and process waste generated at K-25, as well as waste from Y-12 and Oak Ridge National Laboratory and from other DOE installations at Paducah, Portsmouth, and Fernald. Most radioactive waste at K-25 is contaminated with uranium and uranium decay products, with small amounts of fission products.

The K-25 site is active in the program for waste minimization and recycling at the Oak Ridge Reservation. In 1994, the Oak Ridge Reservation recycled about 700 tons (640 metric tons) of paper, 350 tons (320 metric tons) of cardboard, and 30 to 50 tons (27 to 45 metric tons) of aluminum (LMES 1995a).

TABLE 3.15 Summary of Financial Characteristics for the K-25 Site County, City, and School District Regions of Influence

Category	Finances[a] ($ million) ROI Counties	ROI Cities	Category	Finances[a] ($ million) ROI School Districts
Revenues			**Revenues**	
Local sources	66.7	118.6	Local sources	143.6
Fines, fees, permits, etc.	9.1	2.7	State sources	145.7
Intergovernmental	8.9	26.5	Federal sources	3.2
Other	5.4	9.5	Other	1.1
Total	90.1	157.2	Total	323.2
Expenditures			**Expenditures**	
General government	31.5	14.1	Administration	30.2
Safety, health, community services	50.7	91.6	Instruction	189.7
			Services	16.3
Debt service	0.0	2.3	Physical plant	17.2
Other financing sources	1.3	48.6	Other	16.3
Total	83.4	156.6	Total	298.7
Revenues less Expenditures	6.7	0.6	**Revenues less Expenditures**	24.5

[a] Data for fiscal year ending June 30, 1995.

Sources: see Allison and Folga (1997).

3.3.9.1 Wastewater

Treated wastewater at the K-25 site is discharged under NPDES permit TN0002950. In 1994, the discharge was in compliance more than 99% of the time. Sanitary wastewater is processed at the K-1203 sewage treatment plant, which has a capacity of 0.92 million gal/d (3.5 million L/d). In 1994, the average loading to the facility was 0.64 million gal/d (70% of capacity). Currently, there is a project to reline sewer lines to reduce rainfall infiltration (DOE 1996g).

3.3.9.2 Solid Nonhazardous, Nonradioactive Waste

The Oak Ridge Reservation, including the K-25 site, generates about 35,000 yd^3/yr (27,000 m^3/yr) of solid nonhazardous waste. The waste is disposed of at the Y-12 landfill, which has a capacity of 405,000 yd^3 (310,000 m^3) (DOE 1996g). An additional 1.8 million yd^3 (1.4 million m^3)

of capacity will be developed at the landfill. Given current and/or future projected waste loading, the landfill will have approximately 50% of capacity, or 920,000 yd^3 (700,000 m^3), available in the year 2020.

3.3.9.3 Nonradioactive Hazardous and Toxic Waste

The K-25 site generates both RCRA-hazardous and TSCA-hazardous waste. The site operates several RCRA Part B hazardous waste treatment/storage facilities. The majority of the hazardous waste consists of PCB-containing solids and liquids regulated according to TSCA guidelines. In 1992, the site generated 1,124 tons (1,020 metric tons) of PCB waste. The site operates a permitted TSCA incinerator to treat hazardous and LLMW liquids contaminated with PCBs. The incinerator also processes PCB waste from other facilities at the Oak Ridge Reservation and from off-site DOE installations. Total capacity of the TSCA incinerator is 1,800 yd^3/yr (1,400 m^3/yr). The K-25 waste input of 1,300 yd^3/yr (1,000 m^3/yr) (DOE 1996g) represents 70% of incinerator capacity. In 1991, the hazardous waste generation for the Oak Ridge Reservation was 154 yd^3 (118 m^3). On-site storage capacity for hazardous waste is 16,100 yd^3 (12,300 m^3).

3.3.9.4 Low-Level Waste

The K-25 site generated approximately 1,400 yd^3 (1,100 m^3) of solid LLW in 1992. The Oak Ridge Reservation has a compaction/shredding facility with the capacity to treat approximately 1,800 yd^3/yr (1,400 m^3/yr) of LLW. The Oak Ridge Reservation disposed of approximately 1,100 yd^3 (840 m^3) of LLW in 1994. Low-level waste that is not treated or disposed of on-site at the Oak Ridge Reservation is placed in storage, pending either treatment or disposal, or both, at off-site facilities. In 1993, approximately 57,900 yd^3 (44,300 m^3) of LLW was in storage at the K-25 site (DOE 1996g).

3.3.9.5 Low-Level Mixed Waste

The majority of radioactive waste generated at the K-25 site is LLMW. The site LLMW consists of two major categories: (1) aqueous RCRA-hazardous radioactive waste contaminated with corrosives or metals and (2) organic liquids contaminated with PCBs. About 4,000 yd^3 (3,000 m^3) of contaminated soil (LLMW) is stored at the Oak Ridge Reservation.

In 1992, the K-25 site generated 100,000 yd^3 (76,000 m^3) of liquid LLMW. Aqueous LLMW is treated at the K-1407H central neutralization facility, which processes aqueous waste by pH adjustment of corrosives and chemical precipitation of metals. Treated wastewaters are discharged to the NPDES-permitted discharges, which have a capacity of 450,000 yd^3/yr (340,000 m^3/yr). The K-25 TSCA incinerator, with a capacity of 1,800 yd^3/yr (1,400 m^3/yr), is used to treat organic LLMW liquids contaminated with PCBs. Total K-25 input to the TSCA incinerator (both PCB-contaminated radioactive and nonradioactive waste) is approximately 1,300 yd^3/yr (1,000 m^3/yr).

The K-25 site has the capability to treat approximately 6,500 yd^3/yr (5,000 m^3/yr) of liquid LLMW via grout stabilization. The site currently stores 38,000 yd^3 (29,000 m^3) of grouted LLMW (DOE 1996g), with a capacity for 88,600 yd^3 (67,800 m^3) of LLMW container storage. The current inventory of LLMW stored at the Oak Ridge Reservation (and the K-25 site) is proposed to be treated in Oak Ridge Reservation facilities. The planned waste treatment will require more than 20 years to complete (LMES 1995b).

3.3.10 Cultural Resources

An archaeological survey was completed at the K-25 site during 1994. This survey confirmed findings of previous surveys of the Oak Ridge Reservation, which had identified 45 prehistoric sites, 10 of which are potentially eligible for the *National Register of Historic Places*. Twelve of the sites are located near the K-25 site (Fielder 1974). More than 240 historic resources have also been recorded at the Oak Ridge Reservation; six are listed on the *National Register*, and 20 or more may be eligible.

The K-25 site was associated with the Manhattan Project and played a significant role in the production of highly enriched uranium for weapons manufacture between 1944 and 1964. Buildings at the K-25 site were evaluated in 1994. One historic district, the Main Plant Historic District, is eligible for the *National Register*. The district consists of 157 buildings, of which 120 buildings contribute to the district and 37 do not. Eleven additional buildings not adjacent to the district are also considered eligible based on their supporting roles in the uranium-235 enrichment process. The George Jones Memorial Baptist Church and Cemetery (established 1901) is also located on the K-25 site and is included in the *National Register*.

On May 6, 1994, a programmatic agreement concerning management of historic properties on the Oak Ridge Reservation was signed by the DOE Oak Ridge Operations Office, the Advisory Council on Historic Preservation, and the Tennessee State Historic Preservation Officer. This agreement concerned management of significant cultural resources that meet eligibility criteria for listing in the *National Register*. DOE committed to developing a draft cultural resources management plan within 2 years of the signing of the agreement. The draft plan was completed in May 1996 and is currently being reviewed. Once final, this plan will supersede the programmatic agreement.

The Overhill Cherokee occupied part of eastern Tennessee from the 1700s until their relocation to Oklahoma in 1838. However, no religious or sacred sites, burial sites, or resources significant to the Overhill Cherokee have been identified at the K-25 site to date.

3.3.11 Minority and Low-Income Populations

The affected environment for assessing the potential for depleted UF_6 management activities to result in environmental justice impacts was based on data from the U.S. Bureau of the Census (1992a-b). The population residing within a 50-mile (80-km) radius of the K-25 site consists of 6.1% minorities and 16.2% persons with low income (see Appendix C, Section C.8.1).

3.4 ENVIRONMENTAL SETTINGS FOR CONVERSION, LONG-TERM STORAGE, MANUFACTURE AND USE, AND DISPOSAL

The locations of potential conversion, long-term storage, disposal, or manufacturing/use facilities will not be evaluated or selected on the basis of the analysis conducted for this PEIS; site selection will be evaluated at a later time during the second tier of NEPA program activities. Because the evaluation of environmental impacts generally depends to a large degree on site characteristics — such as the population distribution around a site, local air quality and weather, local ecology, and proximity of surface water and subsurface water (groundwater) — representative or generic environmental settings were defined for each of the PEIS categories of options. These environmental settings were defined to provide a reasonable, generalized range of environmental conditions for the purposes of impact assessment in this PEIS. Assumptions for the environmental settings are described further in Chapter 4.

3.4.1 Conversion

For the evaluation of conversion options, the potential environmental setting was assumed to be similar to the settings of the three current cylinder storage sites. Environmental data from the three current sites were used to provide a reasonable range of environmental conditions. The impacts of conversion are presented as ranges based on the differences in conditions represented by data used to define the environmental settings.

3.4.2 Long-Term Storage

Similar to the conversion options, the potential environmental settings for storage in yards, buildings, and vaults were selected on the basis of environmental conditions at the three current cylinder storage sites. The impacts of long-term storage are presented as ranges based on the differences in conditions represented by differences in data used to define the environmental settings. For assessment of mine storage, a generic environmental setting for a dry location was assumed (storage in a wet mine environment was not considered reasonable due to potential corrosion of containers). The environmental conditions of a generic dry setting are discussed in Section 3.4.4.1.

3.4.3 Manufacture and Use

The environmental settings for the manufacture and use options were developed for a manufacturing facility located in a generic dry setting and a generic wet setting. The dry setting would be typical of conditions in the arid western United States, and the wet setting would be typical of conditions in the eastern United States. The conditions assumed for the generic wet and dry settings were the same as those used for the assessment of disposal impacts, described in detail in Sections 3.4.4.1 and 3.4.4.2. For both dry and wet settings, manufacturing impacts were calculated for a rural area with a population density corresponding to 15 persons/mi^2 (6 persons/km^2), 120,000 people within a 50-mile (80-km) radius; and an urban area with a population density of 700 persons/mi^2 (275 persons/km^2), 5,500,000 people within a 50-mile (80-km) radius, respectively.

3.4.4 Disposal

The potential environmental settings for the disposal options were based on data representing a dry setting and a wet setting — as described in Sections 3.4.4.1 and 3.4.4.2. Both the dry and wet settings were assumed to be in a rural environment with an average population density of 15 persons/mi^2 (6 persons/km^2).

3.4.4.1 Generic Setting for a Dry Location

For the representative dry setting, a disposal facility was assumed to be located in an arid to semiarid climate. Under these conditions, annual precipitation typically would be about 10 in./yr (25 cm/yr). Approximately 1% of the annual rainfall (Rice et al. 1989), or about 0.1 in./yr (0.25 cm/yr), would be expected to infiltrate the ground, recharging the groundwater. The remainder of the precipitation would be lost to runoff or evapotranspiration (evaporation plus plant transpiration). No ponded waters would be expected to occur nearby, although it was assumed for assessment purposes that a nearby river could be used to supply raw water and to receive liquid waste discharges. The area would be well drained and free of flooding or frequent ponding.

The dry setting was assumed to be in a relatively flat area, overlying approximately 500 ft (150 m) of unconsolidated soil. This soil material was assumed to consist of sandy gravel and gravelly sand interbedded with lenses of clay, silt, and sand that have a variable thickness from about 1 ft (0.3 m) to more than 30 ft (9.1 m). Caliche (layers cemented together by calcium carbonate and other salts), commonly formed on exposed surfaces, would further limit infiltration. The presence of clay layers would impede vertical contaminant transport to the underlying water table. Because of the arid climate, water content of the soil would generally be less than 10% by volume. The unconsolidated material was assumed to have a limited number of small, discontinuous fractures and no significant voids or flow channels.

The groundwater aquifer was assumed to be located at a depth of about 500 ft (150 m) below the surface. This aquifer was assumed to consist of 100 ft (30 m) of semiconsolidated sands, gravels, silts, and clays.

The assessment of air dispersion following potential releases to the atmosphere was based on historical meteorological conditions for five actual "dry" locations in the southwestern United States to provide a range for impact calculations.

3.4.4.2 Generic Setting for a Wet Location

For the generic wet setting, a disposal facility was assumed to be in a modified continental climate. Under these conditions, annual precipitation would be about 40 in./yr (100 cm/yr). About 50% of the rainfall would be expected to be lost to runoff and evapotranspiration, with the remainder, 20 in./yr (51 cm/yr), infiltrating the ground and recharging the underlying groundwater aquifer (Rice et al. 1989). Because of moderate climatic conditions, nearby surface water features would likely be present; however, the setting would be above the elevation of any 100-year floodplain. It was assumed that a nearby river would be available to supply raw water and to receive liquid waste discharges. The area was assumed to be well drained and free of areas of flooding or frequent ponding.

The wet setting was assumed to be in a relatively flat area, overlying approximately 30 ft (9 m) of unconsolidated soil. This material would consist of layers of sand, gravel, and clay. The presence of clay layers would impede vertical contaminant transport to the underlying water table. Because of frequent rainfall events, the water content of the soil would be high. The unconsolidated material was assumed to have a limited number of small, discontinuous fractures and no significant voids or flow channels. Frost penetration of the uppermost layer of soil would be less than 3 ft (0.9 m).

The groundwater aquifer was assumed to be located at a depth of about 30 ft (9 m) below the surface. This aquifer was assumed to consist of 20 ft (6.1 m) of semiconsolidated sands, gravels, silts, and clays.

The assessment of air dispersion following potential releases to the atmosphere was based on historical meteorological conditions for five actual "wet" locations in the central and southeastern United States to provide a range for impact calculations.

3.4.5 Transportation

Transport of depleted UF_6 cylinders, uranium products, and waste materials would be generally over established highways, interstates, and rail lines in accordance with the applicable routing regulations and guidelines of the DOT and the Federal Railway Administration. For PEIS assessment purposes, representative truck and rail route characteristics were defined on the basis of national averages.

4 ENVIRONMENTAL IMPACT ASSESSMENT APPROACH, ASSUMPTIONS, AND METHODOLOGY

This PEIS evaluates potential impacts on human health and the natural environment from implementing proposed alternative strategies for management of depleted UF_6. These impacts might be positive in the sense that they would improve conditions in the human or natural environment or negative in the sense that they would cause a decline in those conditions. This chapter provides an overview of the methods used to estimate the potential impacts associated with the PEIS alternatives and summarizes the major assumptions that formed the basis of the evaluation. Some background information describing human health impacts from exposure to radiation and chemicals is also provided, and the approach used to account for uncertainties in the estimation of potential environmental impacts is discussed. Additional detailed information on the methodology and assumptions for each area of analysis, including discussions of the analytical models used, is provided in Appendix C.

4.1 GENERAL ASSESSMENT APPROACH

Potential environmental impacts were generally assessed by examining all of the activities required to implement each alternative from 1999 through 2039 (i.e., 41 years) — including the construction of any new facilities required, the operation of new or existing facilities, and the transportation of materials between sites. In addition, for the continued storage component of all alternatives and for the disposal alternative, long-term impacts from potential groundwater contamination were estimated. For continued cylinder storage, potential long-term impacts from cylinder breaches occurring at the sites through the analyzed storage periods were estimated by calculating the maximum groundwater contamination levels possible in the future from those breaches. For the disposal alternative, impacts were estimated for a period up to 1,000 years after the assumed failure of the facility. The impacts of an alternative might occur at one or several sites, as well as along the transportation routes between the sites. For each alternative, potential impacts to workers, members of the general public, and the environment were estimated for both normal operations and for potential accidents.

The PEIS analysis considered all potential areas of impact but emphasized those areas that might have a significant impact on human health or the environment, would differentiate among alternatives, were appropriate for the Phase I programmatic level of analysis, or were of special interest to the public (such as potential radiation effects). For activities that would occur at known locations, the potential impacts were evaluated for the actual sites; for activities at locations that will be determined in the future in Phase II of the Depleted Uranium Hexafluoride Management Program, potential impacts were evaluated for representative or generic settings. Thus, continued storage of cylinders and preparation of cylinders for shipment, if required, would take place at the three current storage sites for all alternatives. However, the locations of potential long-term storage, conversion, manufacture and use, and disposal sites are not yet known, so the analysis considered representative three current storage sites are described in Sections 3.1 through 3.3; representative and generic environmental settings are summarized in Section 3.4.

The estimation of potential environmental impacts was based primarily on information provided in the engineering analysis report (LLNL 1997a), which contains preliminary facility design data for cylinder preparation, conversion, long-term storage (except for long-term storage of cylinders in yards), manufacture and use, and disposal options. For these options, the engineering analysis report includes descriptions of facility layouts, resource requirements, and construction requirements; estimates of effluents, wastes, and emissions during operations; and descriptions and estimated frequencies for a range of potential accident scenarios. (The summary of the engineering analysis report is provided in Appendix O.) Calculation of potential environmental impacts from continued cylinder storage at the current sites and from long-term storage of UF_6 cylinders in yards was based on current management practices (Parks 1997), using assumptions consistent with the engineering analysis report (LLNL 1997a). These facility design data, as well as environmental setting information, were used as input to the calculational models or "tools" for estimating potential environmental impacts that could result under each alternative. The methods for estimating impacts and determining their importance are described for each assessment area in Section 4.3.

The facility descriptions and preliminary designs presented in the engineering analysis report (LLNL 1997a) were based on processing the DOE-generated depleted UF_6 cylinder inventory of 46,422 cylinders over a 20-year period. After the publication of the engineering analysis report and the draft PEIS, responsibility for approximately 11,400 additional depleted UF_6 cylinders (approximately 137,000 metric tons) was transferred from USEC to DOE by the signing of two memoranda of agreement (see Section 1.5.2). Consequently, the analysis in the PEIS was expanded to consider management of up to 15,000 USEC-generated cylinders (approximately 180,000 metric tons). To account for this increase in inventory, the PEIS assessment in Chapter 6 assumes that the facility operational periods would be extended from 20 years to approximately 26 years to process the additional USEC cylinders.

4.2 MAJOR ASSESSMENT ASSUMPTIONS AND PARAMETERS

4.2.1 General Assumptions and Parameters

Several general assumptions and parameters formed the basis of the evaluation of alternatives in this PEIS, as follows:

- ***Cylinder Inventory:*** This PEIS considers the depleted UF_6 inventory stored at the Paducah site, the Portsmouth site, and the K-25 site on the Oak Ridge Reservation for which DOE has management responsibility. This inventory includes depleted UF_6 generated by DOE prior to the formation of USEC in July 1993 and depleted UF_6 generated by USEC that has been or will be transferred to DOE. Specifically, the PEIS analyzes alternatives for the management of 46,422 cylinders generated by DOE and up to 15,000 cylinders generated by USEC. The depleted UF_6 inventory generated by DOE before July 1993 consists of 46,422 cylinders that contain approximately 560,000 metric tons of UF_6; of these, 28,351 are located at Paducah (342,000 metric tons); 13,388 are at Portsmouth (161,000 metric tons); and 4,683 are at K-25 (56,000 metric tons). The PEIS also considers management of up to 15,000 USEC-generated cylinders (approximately 180,000 metric tons). For the purposes of analysis, it was assumed that 12,000 of the USEC-generated cylinders would be managed at Paducah, and 3,000 would be managed at Portsmouth.

DOE is also responsible for managing a total of approximately 200 cylinders at the three sites that contain small amounts of material. (Termed "heels" cylinders, they contain a total of about 2,300 lb of depleted UF_6, less than 0.0002% of the inventory.) A cylinder heel is defined as the residual amount of nonvolatile material remaining in a cylinder after removal of the depleted UF_6. For this PEIS, it has been assumed that the heels cylinders will continue to be safely stored under the cylinder management program. If a management strategy that involves conversion is selected, these existing heels cylinders will be treated in the same way as the heels cylinders that would be generated from the conversion process. Details on the treatment of heels cylinders are given in Appendix F, Section F.2. Any impacts associated with the management of the heels would be very small because of the very small numbers of cylinders and amount of depleted UF_6 handled. The impacts in all technical areas from a cylinder treatment facility that would process all the UF_6 cylinders would generally be low (see Appendix F, Sections F.3.1-F.3.9); therefore, the impacts from the small number of additional heels cylinders would be negligible.

- ***Assessment Period:*** Potential impacts from depleted UF_6 management activities were considered for the period from 1999 through 2039: generally 10 years for siting, design, and construction of required facilities; 20 to 26 years for operations; and, when appropriate, about 4 to 10 years for monitoring.[1] Activities beyond 2039 would be subject to appropriate NEPA reviews and decisions in the future. In addition, for the disposal alternative, impacts were estimated for a period of up to 1,000 years beyond the assumed failure of the facility.

- ***Timing — No Action Alternative:*** Under the no action alternative, the depleted UF_6 cylinder inventory was assumed to be stored indefinitely at the three current storage sites.

[1] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS

- ***Timing — Alternatives Other Than No Action:*** For the alternatives other than no action, the analysis assumed that operation of any required conversion, disposal, manufacturing, or long-term storage facilities would begin by the year 2009. The time between signing of the Record of Decision and facility start-up was assumed to be needed for activities such as technology selection, facility design, site selection and preparation, facility construction, procurement, and appropriate NEPA reviews. Operation of the facilities to process the entire inventory was assumed to continue for up to 26 years (as noted in footnote 1, the timeframe estimates were meant solely to provide a consistent analytical basis and do not represent a definitive schedule). Processing was assumed to occur at a constant rate over the 26 years, at a throughput rate of about 28,000 metric tons per year (as depleted UF_6). Following processing, either monitoring and maintenance of long-term storage or disposal facilities or use as casks would take place through 2039.

4.2.2 Cylinder Assumptions and Parameters

Analysis of the continued management of cylinders at the three current storage sites and the future condition of cylinders was based on the following assumptions and parameters:

- ***Cylinder Monitoring and Maintenance Activities:*** While in storage at the three current storage sites, cylinders were assumed to be inspected and maintained in safe storage consistent with current management practices and plans (LMES 1997i; Parks 1997). These activities include routine cylinder inspections, cylinder painting to control corrosion, and cylinder yard upgrades to improve storage conditions. Maintenance also includes cylinder valve replacement and cylinder repair and replacement, as necessary. These activities are described in detail in Appendix D.

- ***Cylinder Corrosion/Breach Estimates:*** Cylinder maintenance and painting will be employed at the three sites to control cylinder corrosion. Based on information provided in the document "Technical Basis for Cylinder Painting Schedule" (Pawel 1997), the analysis in the PEIS assumed that cylinder maintenance and painting activities would halt further corrosion of the cylinders. However, because of uncertainties associated with the effectiveness of cylinder painting in stopping corrosion and uncertainties in the painting schedule, an analysis was also conducted assuming that the cylinders would continue to corrode at rates estimated from historical data prior to initiation of storage condition improvements and cylinder painting. A detailed description of the assumptions used to estimate the incidence of cylinder breaches is provided in Appendix B; the impacts of continued cylinder storage are described in Appendix D for each of the three current storage sites.

- ***Preparation of Cylinders for Shipment:*** A portion of the cylinder inventory might not be suitable for off-site transportation without some type of preparation (see Appendix E). It is currently uncertain how many cylinders might not meet transportation requirements in the future. Thus, impacts were evaluated for the preparation of a range of cylinders (about 30 to 100% of the DOE-generated inventory) at each site, as follows: 9,600 to 28,351 cylinders at Paducah, 2,600 to 13,388 cylinders at Portsmouth, and 2,342 to 4,683 cylinders at K-25.

4.2.3 Environmental Setting Assumptions and Parameters

The assessment of environmental impacts considered three types of environmental settings for evaluating different management activities. These settings are summarized in Table 4.1 and as follows:

- *Existing Settings (Current Storage Sites):* Activities necessary to maintain the continued safe storage of cylinders at the current storage sites and activities necessary to remove the cylinders from these sites were assessed using data specific to those sites.

- ***Representative Environmental Settings:*** The environmental impacts of potential conversion and long-term storage facilities (yards, buildings, and vaults) were evaluated using a range of representative site conditions. For purposes of analysis, the range of environmental conditions present at the current storage sites was used as the representative range for the potential conversion or long-term storage facilities. Because of the large quantities of material to be shipped and consequent costs, these facilities might be located at relatively short distances from the current storage sites. However, sites outside of the region of the current storage sites, including any private facilities that now exist or might be built in the future, would be included among the reasonable range of alternatives that would be evaluated in the site-selection process. The current storage sites have a well documented and comparable set of environmental data on both the natural environment and on operations of facilities handling depleted UF_6. Use of such data allows for a comprehensive assessment of impacts associated with potential conversion and long-term storage facilities.

- ***Generic Environmental Settings***: The environmental impacts of potential facilities for manufacturing, long-term storage in a mine, and disposal were assessed using generic environmental settings. These settings were selected from locations in either a dry environment (representative of the western United States) or a wet environment (representative of the eastern United States) (Table 4.1).

4.3 IMPACT ASSESSMENT METHODOLOGIES

In general, the activities assessed in this PEIS could affect workers, members of the general public, and the environment during construction of new facilities, during routine operations of existing or new facilities, during transportation, and during facility or transportation accidents. Activities could have adverse effects (e.g., human health impairment) or positive effects (e.g., regional socioeconomic benefits, such as the creation of jobs). Some impacts would result primarily from the unique characteristics of uranium and other chemical compounds handled or generated under the alternatives. Other impacts would occur regardless of the types of materials involved, such as impacts on air or water quality from construction activities or vehicle-related impacts resulting from transportation.

The areas of potential environmental impacts evaluated in the PEIS are shown in Figure 4.1 (the order of presentation does not imply relative importance). For each area, different analytical methods were used to estimate the potential impacts from construction, operations, and accidents for each of the PEIS alternatives. The assessment methodologies are summarized in Sections 4.3.1 through 4.3.13; additional detailed information, such as descriptions of computer models used, are presented in Appendix C.

Throughout the PEIS, the results of the impact analyses are summarized for each area of impact using the criteria defined in Table 4.2. The criteria are defined differently for each area because of differences in the nature of the impacts. For example, impacts to human health are summarized quantitatively in the PEIS by presenting the estimated number of health effects among workers and members of the general public. 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, are summarized qualitatively in the PEIS using the terms negligible to low, moderate, and large (as defined in Table 4.2).

4.3.1 Human Health — Normal Facility Operations

Human health impacts were estimated for three types of potential exposures: exposure to radiation, exposure to chemicals, and exposure to physical hazards (e.g., on-the-job injuries or fatalities from falls, lifting, or equipment malfunctions). These potential human exposures could occur in and around facilities or during transportation of materials among the facilities. Exposures

TABLE 4.1 Summary of Environmental Setting Assumptions

Management Activity	Environmental Setting[a]	Assumptions and Approach
Continued cylinder storage	Site-specific	Impacts were calculated specifically for the Paducah, Portsmouth, and K-25 (Oak Ridge Reservation) sites.
Cylinder preparation	Site-specific	Impacts were calculated specifically for the Paducah, Portsmouth, and K-25 sites.
Conversion	Representative	The environmental settings of the three current storage sites were used to create a representative range of environmental conditions.
Long-term storage	Representative	*Yards, Buildings, Vaults* — The environmental setting and analysis of impacts are similar to those for the conversion category of options.
	Generic	*Mine* — A new mine, located in a generic "dry" environment, was assumed. The mine would be located 400 ft below the ground surface (100 ft above the water table) in an area having 10 in. precipitation per year.
Manufacture and use	Generic	A range of meteorological conditions, based on five eastern and five western U.S. locations, was used to determine air dispersion. Impacts were calculated for both generic rural (6 persons/km^2) and urban (275 persons/km^2) locations.
Disposal	Generic	Two generic settings with low population densities (6 persons/km^2) were considered: *Wet setting* — Disposal facility located 30 ft above the water table in an area having 40 in. precipitation per year; five example eastern locations were used to determine a range of meteorological conditions for air dispersion. *Dry setting* — Disposal facility located either 500 ft (shallow earthen structure and vault) or 100 ft (mine) above the water table in an area having 10 in. precipitation per year; five example western locations were used to determine a range of meteorological conditions for air dispersion.

[a] Because actual sites for the conversion, long-term storage, manufacture and use, and disposal alternatives will be identified in Phase II studies and NEPA reviews, representative or generic environmental settings were used to analyze potential impacts.

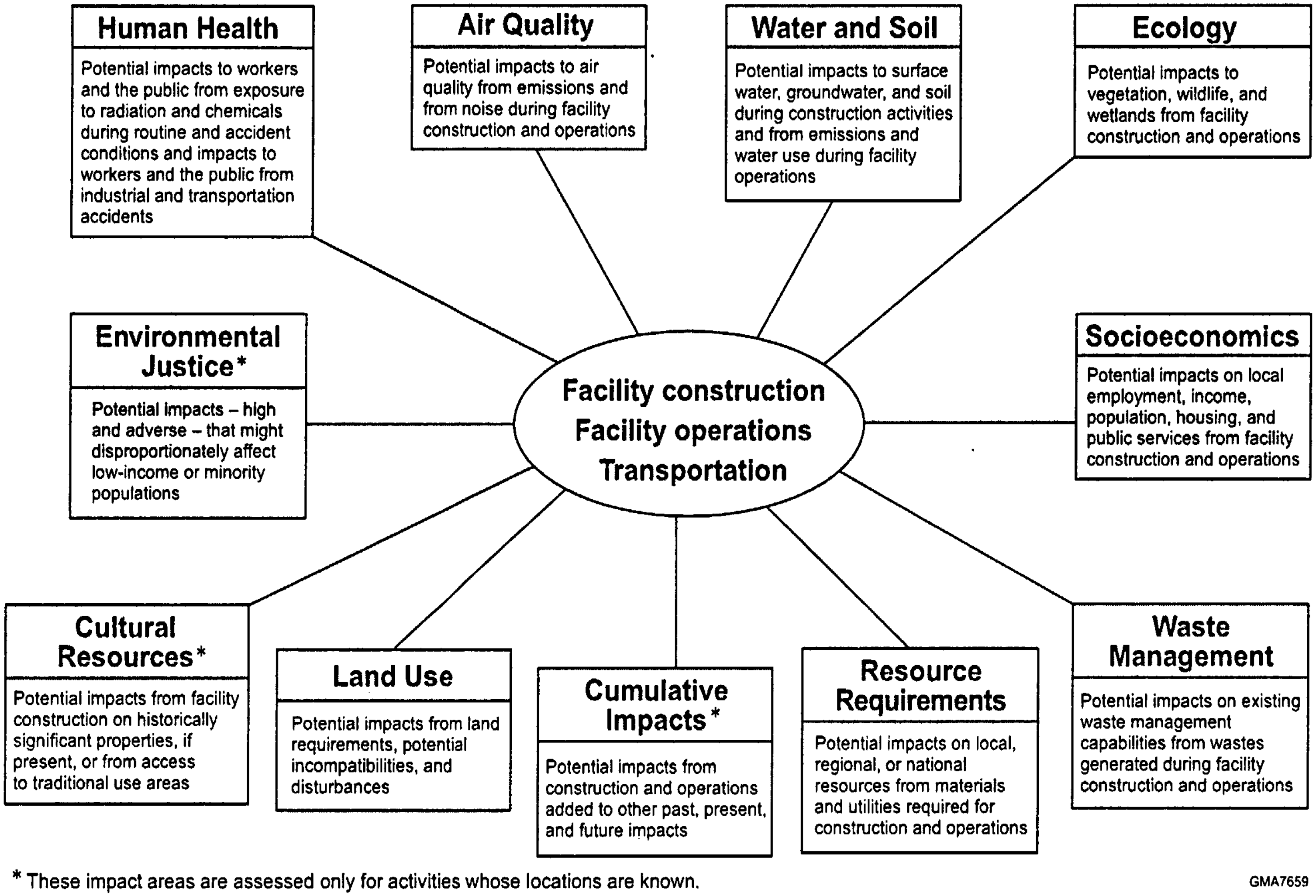

FIGURE 4.1 Areas of Potential Impact Evaluated in the PEIS for Each Alternative

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

	General Criteria Used to Define Descriptor Term		
Area of Impact	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).		

TABLE 4.2 (Cont.)

Area of Impact	General Criteria Used to Define Descriptor Term: Negligible to Low	Moderate	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).		
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.

TABLE 4.2 (Cont.)

Area of Impact	General Criteria Used to Define Descriptor Term		
	Negligible to Low	Moderate	Large
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.
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, congestion at intersections, with a high level-of-service rating; general guideline of land-use requirement of greater 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.		

could take place during incident-free (normal) operations or following potential accidents in the facilities or during transportation. Assessment methodologies for estimating the impacts resulting from normal facility operations are discussed in Sections 4.3.1.1 and 4.3.1.2. Methods for assessing facility accident impacts are described in Section 4.3.2, and transportation impacts are discussed in Section 4.3.3.

The nature of the potential impacts resulting from the three types of exposure would differ. Table 4.3 lists and compares the key features of these types of exposures. Because of the differences in these features, it is not always appropriate to combine impacts from different exposures to get a total impact for a given human receptor.

4.3.1.1 Radiological Impacts

4.3.1.1.1 Radiation

All of the PEIS alternatives would involve handling compounds of the element uranium, which is radioactive. Radiation, which occurs naturally, is released when one form of an element (an isotope) changes into some other atomic form. This process, called radioactive decay, occurs because unstable isotopes tend to transform into a more stable state. The radiation emitted may be in the form of particles such as neutrons, alpha particles, and beta particles; or waves of pure energy such as gamma rays.

The radiation released by radioactive materials (i.e., alpha, beta, and gamma radiation) can impart sufficient localized energy to living cells to cause cell damage. This damage may be repaired by the cell, the cell may die, or the cell may reproduce other altered cells, sometimes leading to the induction of cancer. An individual may be exposed to radiation from outside the body (called external exposure) or, if the radioactive material has entered the body through inhalation (breathing) or ingestion (swallowing), from inside the body (called internal exposure).

Everyone is exposed to radiation on a daily basis, primarily from naturally occurring cosmic rays, radioactive elements in the soil, and radioactive elements incorporated in the body. Man-made sources of radiation, such as medical X-rays or fallout from historical nuclear weapons testing, also contribute, but to a lesser extent. About 80% of background radiation originates from naturally occurring sources, with the remaining 20% resulting from man-made sources.

The amount of exposure to radiation is commonly referred to as "dose." The estimation of radiation dose takes into account many factors, including the type of radiation exposure (neutron, alpha, gamma, or beta), the different effects each type of radiation has on living tissues, the type of exposure (i.e., internal or external), and, for internal exposure, the fact that radioactive material may be retained in the body for long periods of time. The common unit for radiation dose that accounts for these factors is the rem (1 rem equals 1,000 mrem).

TABLE 4.3 Key Features of Potential Human Exposures to Radiological, Chemical, and Physical Hazards

	Potential exposures		
Feature	Radiological	Chemical	Physical Hazard
Materials of concern in the PEIS	Uranium and its compounds	Uranium and its compounds, HF, and ammonia.	Physical hazards associated with all facilities and transportation conditions.
Health effects	Radiation-induced cancer incidence and fatality would occur a considerable time after exposure (typically 10 to 50 years). The risks were assessed in terms of latent cancer fatalities (LCFs).	Adverse health effects (e.g., kidney damage and respiratory irritation or injury) could be immediate or could develop over time (typically less than 1 year).	Impacts would result from occurrences in the workplace or during transportation that were unrelated to the radiological and/or chemical nature of the materials being handled. Potential impacts would include bodily injury or death due to falls, lifting heavy objects, electrical fires, and traffic accidents.
Receptor	Generally the whole body of the receptor would be affected by external radiation, with internal organs affected by ingested or inhaled radioactive materials. Internal and external doses were combined to estimate the effective dose equivalent (see Appendix C).	Generally certain internal organs (e.g., kidneys and lungs) of the receptor would be affected.	Generally the whole body of the receptor could be affected.
Threshold	No radiological threshold exists before the onset of impacts, i.e., any radiation exposure could result in LCFs. To show the significance of radiation exposures, estimated radiation doses were compared with existing regulatory limits.	A chemical threshold exposure level exists (different for each chemical) below which exposures are considered safe (see Section 4.3.1.2). Where exposures were calculated at below threshold levels, "no impacts" were reported.	No threshold exists for physical hazards. Impact estimates were based on the statistical occurrence of impacts in similar industries and on the amount of labor required.

In the United States, the average dose from background radiation is about 360 mrem/yr per person, of which about 300 mrem is from natural sources. For perspective, the radiation doses resulting from a number of common activities are provided in Table 4.4. The total dose to an individual member of the general public from DOE and other federal activities is limited by law to 100 mrem/yr (in addition to background radiation), and the dose to a member of the public from airborne emissions released from DOE facilities must be below 10 mrem/yr (40 CFR Part 61).

4.3.1.1.2 Radiation Doses and Health Effects

Radiation exposure can cause a variety of adverse health effects in humans. Very large doses of radiation (about 450,000 mrem) delivered rapidly can cause death within days to weeks from tissue and organ damage. The potential adverse effect associated with the low doses typical of most environmental and occupational exposures is the inducement of cancers that may be fatal. This latter effect is called "latent" cancer fatality (LCF) because the cancer may take years to develop and cause death. In general, cancer caused by radiation is indistinguishable from cancer caused by other sources.

Key Concepts in Estimating Risks from Radiation

The health effect of concern from exposure to radiation at levels typical of environmental and occupational exposures is the inducement of cancer. Radiation-induced cancers may take years to develop following exposure and are generally indistinguishable from cancers caused by other sources. Current radiation protection standards and practices are based on the premise that any radiation dose, no matter how small, can result in detrimental health effects (cancer) and that the number of effects produced are in direct proportion to the radiation dose. Therefore, doubling the radiation dose is assumed to result in doubling the number of induced cancers. This approach is called the "linear-no- threshold hypothesis" and is generally considered to result in conservative estimates (i.e., overestimates) of the health effects from low doses of radiation.

For this PEIS, radiation effects were estimated by first calculating the radiation dose to workers and members of the general public from the anticipated activities required under each alternative. Doses were estimated for internal and external exposures that might occur during normal (or routine) operations and following hypothetical accidents. The analysis considered three groups of people: (1) involved workers, (2) noninvolved workers, and (3) members of the general public, defined as follows:

- ***Involved Workers*** — Persons working at a site who are directly involved with the handling of radioactive or hazardous materials:

  - Might be exposed to direct gamma radiation emitted from radioactive materials, such as depleted UF_6 or other uranium compounds.

TABLE 4.4 Comparison of Radiation Doses from Various Sources

Radiation Source	Dose to an Individual
Annual background radiation — U.S. average	
Total	360 mrem/yr
From natural sources (cosmic, terrestrial, radon)	300 mrem/yr
From man-made sources (medical, consumer products, fallout)	60 mrem/yr
Daily background radiation — U.S. average	1 mrem/d
Increase in cosmic radiation dose due to moving to a higher altitude, such as from Miami, Florida, to Denver, Colorado	25 mrem/yr
Chest X-ray	10 mrem
U.S. transcontinental flight (5 hours)	2.5 mrem
Dose from naturally occurring radioactive material in agricultural fertilizer — U.S. average	1 to 2 mrem/yr
Dose from standing 6 ft (2 m) from a full depleted UF_6 cylinder for 5 hours	1 mrem

Sources: NCRP (1987a,c).

- Would receive very small radiation doses from inhaling uranium compared with the direct radiation doses because most processes would be enclosed and ventilation controls would be used to inhibit airborne emissions in facilities.

- Would be protected by a dosimetry program to monitor and control doses below the regulatory limit of 5 rem/yr for workers (10 CFR Part 835).

• ***Noninvolved Workers*** — Persons working at a site but not directly involved with the handling of radioactive or hazardous materials:

  - Might be exposed to direct radiation from radioactive materials (although at a great distance) and to trace amounts of uranium released to the environment through site exhaust stacks.

  - Would receive radiation exposure primarily through inhalation of radioactive material in the air, external radiation from radioactive material deposited on the ground, and incidental ingestion of soil.

- ***Members of the General Public*** — Persons living within 50 miles (80 km) of the site:
  - Might be exposed to trace amounts of uranium released to the environment through exhaust stacks or wastewater discharges.
  - Would receive radiation exposures primarily through inhalation of radioactive material in the air, external radiation from deposited radioactive material on the ground, and ingestion of contaminated water, food, or soil.

For each of these groups, doses were estimated for the group as a whole (population or collective dose). For noninvolved workers and the general public, doses were also estimated for a MEI. The MEI was defined as a hypothetical person who — because of proximity, activities, or living habits — could receive the highest possible dose. The MEI for noninvolved workers and members of the general public usually was assumed to be at the location of the highest on-site or off-site air concentrations of contaminants, respectively — even if no individual actually worked or lived there. Under actual conditions, all radiation exposures and releases of radioactive material to the environment are required to be kept as low as reasonably achievable (ALARA), a practice that has as its objective the attainment of dose levels as far below applicable limits as possible.

Following estimation of the radiation dose, the number of potential LCFs was calculated using health risk conversion factors. These factors relate the radiation dose to the potential number of expected LCFs based on comprehensive studies of groups of people historically exposed to large doses of radiation, such as the Japanese atomic bomb survivors. The factors used for the analysis in this PEIS were 0.0004 LCF/person-rem of exposure for workers and 0.0005 LCF/person-rem of exposure for members of the general public (International Commission on Radiological Protection [ICRP] 1991). The latter factor is slightly higher because some individuals in the public, such as infants, are more sensitive to radiation than the average worker. These factors imply that if a population of workers receives a total dose of 2,500 person-rem, on average, 1 additional LCF will occur among the workers. Similarly, if the general public receives a total dose of 2,000 person-rem, on average, 1 additional LCF will occur.

The calculation of human health effects from radiation is relatively straightforward. For example, assume the following situation:

- Each of 100,000 persons receives a radiation dose equal to background, or 360 mrem/yr (0.36 rem/yr), and
- The health risk conversion factor for the public is 0.0005 LCF/person-rem.

In this case, the number of radiation-induced LCFs caused by 1 year of exposure among the population would be 1 yr × 100,000 persons × 0.36 rem/yr × 0.0005 LCF/person-rem, or about 18 cancer cases, which would occur over the lifetimes of the individuals exposed. For perspective, in the same population of 100,000 persons, a total of about 23,000 (23%) would be expected to die of cancer from all causes over their lifetimes (Centers for Disease Control and Prevention 1996).

Sometimes the estimation of number of LCFs does not yield whole numbers and, especially in environmental applications, yields numbers less than 1. For example, if 100,000 persons were exposed to 1 mrem (0.001 rem) each, the estimated number of LCFs would be 0.05. The estimate of 0.05 LCF should be interpreted statistically — as the average number of deaths if the same radiation exposure were applied to many groups of 100,000 persons. In most groups, no one (zero persons) would incur an LCF from the 1 mrem exposure each person received. In some groups, 1 LCF would occur, and in exceptionally few groups, two or more LCFs would occur. The average number of deaths would be 0.05 (just as the average of 0, 0, 0, and 1 is 0.25). The result, 0.05 LCF, may also be interpreted as a 5% chance (1 in 20) of one radiation-induced LCF in the exposed population. In the PEIS, fractional estimates of LCFs were rounded to the nearest whole number for purposes of comparison. Therefore, if a calculation yielded an estimate of 0.6 LCF, the outcome is presented in the PEIS as 1 LCF, the most likely outcome.

The same concept is assumed to apply to exposure of a single individual, such as the MEI. For example, the chance that an individual exposed to 360 mrem/yr (0.36 rem/yr) over a lifetime of 70 years would die from a radiation-induced cancer is about 0.01 (0.36 rem/yr × 0.0005 LCF/rem × 70 yr = 0.01 LCF). Again, this should be interpreted statistically; the estimated effect of radiation on this individual would be a 1% (1 in 100) increase in the chance of incurring an LCF over the individual's lifetime. The risk to individuals in the PEIS is generally presented as the increased chance that the individual exposed would die from a radiation-induced cancer.

4.3.1.2 Chemical Impacts

4.3.1.2.1 Chemicals of Concern

All alternatives considered in the PEIS would involve the handling of chemicals that could adversely affect human health. The chemicals of greatest concern for this analysis are soluble and insoluble uranium compounds and HF. In addition to being radioactive, uranium compounds can cause chemical toxicity to the kidneys; soluble uranium compounds are more toxic than insoluble compounds because soluble compounds are more readily absorbed into the body. Hydrogen fluoride is a corrosive gas that can cause respiratory irritation in humans, with tissue destruction or death resulting from exposure to large concentrations of HF. The actual amount of this gas that could be fatal to humans is not known precisely because levels are difficult to measure; no deaths have been known to occur as a result of acute exposures (i.e., 1 hour or less) of animals or humans at concentrations of less than 50 ppm (AIHA 1988).

Although uranium compounds and HF would be of greatest concern, potential human health impacts from the use of other chemicals were also considered. For example, conversion would require the use of various chemicals (e.g., nitric acid, ammonia, and trichloroethylene). In general, during routine conditions, potential exposures to these chemicals would be limited to involved workers, who would be protected through industrial hygiene programs. In the engineering analysis report (LLNL 1997a), reported emissions through process stacks of chemicals other than uranium compounds and HF were generally for chemicals with very low toxicity (e.g., calcium, magnesium, phosphates, chloride) or for categories of chemicals with no toxicity criteria available (e.g., copolymers and phosphonates). Therefore, in the PEIS, quantitative risk analysis for exposure to chemicals under routine conditions was limited to uranium compounds and HF. (Limited calculations were also conducted for trichloroethylene emissions from one of the UO_2 conversion options; estimated emission levels were very low and would not result in adverse impacts.) For accident conditions, several chemicals were evaluated (e.g., hydrochloric acid, nitric acid, and sulfuric acid), but quantitative risk analysis was conducted only for uranium compounds, HF, and ammonia because the other compounds would be used in either small quantities or dilute formulations.

Key Concepts in Estimating Risks from Low-Level Chemical Exposures

Reference Dose:

- Intake level of a chemical below which adverse effects are very unlikely (also known as the threshold level).

Hazard Quotient:

- A comparison of the estimated intake level or dose of a chemical with its reference dose.
- Expressed as a ratio of estimated intake level to reference dose.
- For example:
  - The reference dose for ingestion of soluble compounds of uranium is 0.003 mg/kg of body weight per day.
  - If a 150-lb (70-kg) person ingested 0.1 mg of soluble uranium per day, the daily rate would be $0.1 \div 70 \approx 0.001$ mg/kg, which is below the reference dose and thus unlikely to cause adverse health effects. This would yield a hazard quotient of $0.001 \div 0.003 = 0.33$.

Hazard Index:

- Sum of the hazard quotients for all chemicals to which an individual is exposed.
- A value less than 1 indicates that the exposed person is unlikely to develop adverse human health effects.

4.3.1.2.2 Chemical Intakes and Health Effects

For long-term, low-level (chronic) exposures to uranium compounds and HF emitted during routine operations, potential adverse health effects for noninvolved workers and members of the public were calculated by estimating the intake levels associated with anticipated activities required under each alternative. Intake levels were then compared to reference doses below which adverse effects are very unlikely (i.e., a threshold) (see Appendix C for discussion of appropriate chemical-specific reference doses). Because the compounds of concern are not chemical carcinogens, cancer risk calculations were not applicable. Risks from routine operations were quantified as hazard quotients and hazard indices (see text box).

The same three groups of people evaluated for radiation exposures were considered in estimating chemical health impacts from chronic exposures: involved workers, noninvolved workers, and members of the general public. Chemical exposures for involved workers would depend in part on detailed facility designs to be determined during Phase II activities; the workplace environment would be monitored to ensure that airborne chemical concentrations were below applicable exposure limits. Potential chemical impacts (in terms of hazard indices) were estimated for noninvolved workers and members of the general public. The main source of impacts to noninvolved workers and members of the public would be the emission of trace amounts of uranium compounds or HF from exhaust stacks. Wastewater discharges also would be a potential source of chemical impacts for members of the public.

For routine operations, the potential impacts to the MEI of a group of people was estimated by calculating a hazard index. If no adverse effects would be expected for either the noninvolved worker MEI or member of the public MEI (i.e., the hazard index was less than 1), by definition no adverse effects would be expected in those populations. Therefore, in such cases, the calculation of population risks was not applicable. If the estimated hazard indices for the MEIs were greater than 1, the population risk would be estimated as the number of individuals who might experience adverse health impacts (the number expected to be exposed at levels that would result in a hazard index greater than 1).

4.3.2 Human Health — Facility Accidents

The PEIS analysis considered a range of potential accidents that could occur at the facilities required by each alternative. An accident is defined as a series of unexpected or undesirable events leading to a release of radioactive or hazardous material within a facility or into the natural environment. Because an accident could involve a large and uncontrolled release, such an event potentially could pose considerable health risks to workers and members of the general public. Two important elements must be considered in the assessment of risks from accidents: the consequence of the accident and the expected frequency (or probability) of the accident.

4.3.2.1 Accident Consequences

The term accident consequence refers to the estimated impacts if an accident were to occur — including health effects such as fatalities. For accidents involving releases of radioactive material, the consequences are expressed in the same way as the consequences from routine operations — that is, LCFs are estimated for the MEI and for populations on the basis of estimated doses from all important exposure pathways. As long as the dose to an individual from accidental exposure is less than 20 rem and the dose rate is less than 10 rem/h, the health risk conversion factors are applicable, and the only important health impact is the LCF — that is, at those relatively low doses and dose rates, other possible radiation effects such as fatalities from acute radiation syndrome, reproductive impairment, or cataract formation do not need to be considered.

Assessing the consequences of accidental releases of chemicals differs from the assessment of routine chemical exposures, primarily because the reference doses used to generate hazard indices for long-term, low-level exposures were not intended for use in the evaluation of the short-term (e.g., duration of several hours or less), higher-level exposures often accompanying accidents. Additionally, the analysis of accidental releases often requires evaluation of different chemicals, especially irritant gases, which can cause tissue damage at higher levels associated with accidental releases but are not generally associated with adverse effects from chronic, low-level exposures.

> **Health Effects from Accidental Chemical Releases**
>
> The impacts from accidental chemical releases were estimated by determining the numbers of people downwind who might experience adverse effects and irreversible adverse effects:
>
> ***Adverse effects*** – Any adverse health effects from exposure to a chemical release, ranging from mild and transient effects, such as respiratory irritation or skin rash (associated with lower chemical concentrations), to irreversible (permanent) effects including death or impaired organ function (associated with higher chemical concentrations).
>
> ***Irreversible adverse effects*** – A subset of adverse effects, irreversible adverse effects are those that generally occur at higher concentrations and are permanent in nature. Irreversible effects may include death, impaired organ function (such as central nervous system or lung damage), and other effects that may impair everyday functions.

To estimate the consequences of chemical accidents, two potential health effects endpoints were evaluated: (1) adverse effects and (2) irreversible adverse effects. Potential adverse effects range from mild and transient effects — such as respiratory irritation, redness of the eyes, and skin rash — to more serious and potentially irreversible effects. Potential irreversible adverse effects are defined as effects that generally occur at higher concentrations and are permanent in nature — including death, impaired organ function (such as damaged central nervous system or lungs), and other effects that may impair everyday functions. For uranium compounds, an intake of 10 mg or more was assumed to cause potential adverse effects (McGuire 1991), and an intake of 30 mg or more was assumed to cause potential irreversible adverse effects. This intake level is based on NRC guidance (NRC 1994a). For HF and ammonia, potential adverse effects levels were assumed to occur at levels that correspond to Emergency Response Planning Guideline (ERPG) No. 1 (ERPG-1) or ERPG-1-equivalent levels, and potential irreversible adverse effects levels were assumed to occur at levels that correspond to ERPG-2 or ERPG-2-equivalent levels. The ERPG values have been generated by teams of toxicologists who review all published (as well as some unpublished) data for a given chemical (AIHA 1996).

In addition, the number of fatalities from accidental chemical exposures was estimated. For exposures to uranium and HF, it was estimated that the number of fatalities occurring would be about 1% of the number of irreversible adverse effects (EPA 1993; Policastro et al. 1997). Similarly, for exposure to ammonia, the number of fatalities was estimated to be about 2% of the number of irreversible adverse effects (Policastro et al. 1997).

Human responses to chemicals do not occur at precise exposure levels but can extend over a wide range of concentrations. However, in this PEIS, the values used to estimate the number of potential chemical effects should be applicable to most individuals in the general population. In all populations, there are hypersensitive individuals who will show adverse responses at exposure concentrations far below levels at which most individuals would normally respond (AIHA 1996). Similarly, many individuals will show no adverse response at exposure concentrations even somewhat higher than the guideline values. For comparative purposes in this PEIS analysis, use of the guideline values discussed above allowed a uniform comparison of the impacts from potential accidental chemical releases across all alternatives.

For both radiological and chemical accidents, consequences were estimated for noninvolved workers on the site and members of the public in the vicinity of the site. The consequences for these two groups were estimated for collective populations as well as hypothetical MEIs. The noninvolved worker population included all workers on the site who were more than 330 ft (100 m) from the accident location (including those working in the facility where the accident occurred). The general public consisted of the population living within 50 miles (80 km) of the accident location. The MEIs were generally assumed to be at the location that would yield the greatest impact following the accident.

During an accident, involved workers might be subject to severe physical and thermal (fire) forces and could be exposed to releases of chemicals and radiation. The risk to involved workers is very sensitive to the specific circumstances of each accident and 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 and thermal 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 are not quantified in this PEIS. However, it is recognized that injuries and fatalities among involved workers are possible from chemical, radiological, and physical forces if an accident did occur.

Accident consequences to noninvolved workers and the public were estimated by using air dispersion models to predict the downwind air concentrations following a release. These models consider a number of factors, including characteristics of the material released, location of the release, meteorological conditions, and whether or not the accident involves a fire. The air concentrations were used to estimate the number of persons potentially experiencing health effects, either LCFs for radiological releases or adverse and irreversible adverse effects for chemical releases (estimated fatalities from HF and ammonia exposures are also provided). The consequences were estimated with the assumption that the wind was blowing in the direction that would yield the greatest impacts.

Additional details concerning the accident assessment methodology are provided in Appendix C (Section C.4 for radiological accidents and Section C.5 for chemical accidents).

> **Accident Categories and Frequency Ranges**
>
> **Likely (L):** Accidents estimated to occur one or more times in 100 years of facility operations (frequency $\geq 1 \times 10^{-2}$/yr).
>
> **Unlikely (U):** Accidents estimated to occur between once in 100 years and once in 10,000 years of facility operations (frequency = from 1×10^{-2}/yr to 1×10^{-4}/yr).
>
> **Extremely Unlikely (EU):** Accidents estimated to occur between once in 10,000 years and once in 1 million years of facility operations (frequency = from 1×10^{-4}/yr to 1×10^{-6}/yr).
>
> **Incredible (I):** Accidents estimated to occur less than one time in 1 million years of facility operations (frequency $< 1 \times 10^{-6}$/yr).

4.3.2.2 Accident Frequencies

The expected frequency of an accident, or its probability of occurrence, is the chance that the accident might occur while conducting an operation. Probabilities range from 0.0 (no chance of occurring) to 1.0 (certain to occur). If an accident is expected to happen once every 50 years, the frequency of occurrence is 0.02 per year: 1 occurrence every 50 years = 1 ÷ 50 = 0.02 occurrence per year. A frequency estimate can be converted to a probability statement. If the frequency of an accident is 0.02 per year, the probability of the accident occurring sometime during a 10-year program is 0.2 (10 years × 0.02 occurrence per year).

The accidents evaluated in this PEIS were anticipated to occur over a wide range of frequencies, from once every few years to less than once in 1 million years. In general, the more unlikely it would be for an accident to occur (the lower its probability), the greater the expected consequences. For the assessment of management alternatives, accidents were evaluated for each activity required for four frequency categories: likely, unlikely, extremely unlikely, and incredible (see text box). To interpret the importance of a predicted accident, the analysis considered the estimated frequency of occurrence of that accident. Although the predicted consequences of an incredible accident might be high, the lower consequences of a likely accident, that is, one much more likely to occur, might be considered more important.

4.3.2.3 Accident Risk

The term "accident risk" refers to a quantity that considers both the severity of an accident (consequence) and the probability that the accident will occur. Accident risk is calculated by multiplying the consequence of an accident by the accident probability. For example, if a facility accident has an estimated frequency of occurrence of once in 100 years (probability = 0.01 per year) and the estimated consequence, if the accident occurred, was 10 LCFs among the people exposed, then the risk of the accident would be reported as 0.1 LCF per year (0.01 per year × 10 LCFs). If the facility were operated for a period of 20 years, the accident risk over the operational phase of the facility would be 2 LCFs (20 years × 0.1 LCF per year).

This definition of accident risk was used to compare accidents that have different frequencies and consequences. Certain high-frequency accidents that have relatively low consequences might pose a larger overall risk than low-frequency accidents that have potentially high consequences. When calculating accident risk, the consequences have been expressed in terms of LCFs for radiological releases or adverse health effects, irreversible adverse health effects, and fatalities for chemical releases.

4.3.2.4 Physical Hazard (On-the-Job) Accidents

Physical hazards, unrelated to radiation or chemical exposures, were assessed for each alternative by estimating the number of on-the-job fatalities and injuries that could occur among workers. These impacts were calculated using industry-specific statistics from the U.S. Bureau of Labor Statistics, as reported by the National Safety Council (1995). The injury incidence rates were for injuries involving lost workdays (excluding the day of injury). The analysis calculated the predicted number of worker fatalities and injuries as the product of the appropriate annual incidence rate, the number of years estimated for the project, and the number of full-time-equivalent employees required for the project each year. Estimates for construction and operation of the facilities were computed separately because these activities have different incidence statistics. The calculation of fatalities and injuries from industrial accidents was based solely on historical industry-wide statistics and therefore did not consider a threshold (i.e., any activity would result in some estimated risk of fatality and injury). The selected alternative for managing depleted UF_6 would be implemented in accordance with DOE or industry best management practices, thereby reducing fatality and injury incidence rates.

4.3.3 Human Health and Safety — Transportation

Transportation of radioactive materials and chemicals would involve potential impacts to both crew members and members of the general public. In this PEIS, impacts were assessed that could arise from the radioactive or chemical nature of the cargo and also from the nature of transportation itself, independent of the cargo. Transportation risks were evaluated for all of the materials that could potentially be transported for each alternative, including UF_6 cylinders, uranium conversion products, HF and other chemicals, and process waste. Transportation impacts were estimated for shipment by both truck and rail modes for most materials. Because the location for some management activities will be determined in Phase II analyses and NEPA reviews, transportation impacts were estimated for a range of distances using representative route characteristics.

For radioactive materials, the cargo-related impacts on human health during transportation would be caused by exposure to ionizing radiation. Radiological risks (i.e., risks that result from the radioactive nature of the cargo) were assessed for both routine (normal) transportation and for accidents. The radiological risk associated with routine transportation results from the potential exposure of persons to low levels of external radiation in the vicinity of a loaded shipment. The radiological risk from transportation-related accidents is associated with the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of persons through multiple pathways (e.g., inhalation of airborne contaminants or the ingestion of contaminated food).

For chemicals, the cargo-related impacts to human health during transportation would be caused by exposure occurring as a result of container failure and chemical release during an accident. Therefore, chemical risks (i.e., risks that result from the toxicity of the chemical composition of the material transported) were assessed for cargo-related transportation accidents. The chemical risk from transportation-related accidents is associated with the potential release, transport, and dispersion of chemicals into the environment and the subsequent exposure of persons, primarily through inhalation exposure. Unlike the radiological risks, there are no chemical risks during routine transport because the materials are sealed in their shipping packages.

In addition to potential cargo-related impacts, impacts were assessed for vehicle-related hazards that are independent of the radioactive or chemical nature of the cargo and could be incurred for similar shipments of any commodity. Vehicle-related impacts were assessed for both routine conditions and accidents. Impacts during routine transportation could result from exposure to vehicular exhaust emissions. Impacts not related to the shipment contents during transportation accidents could result from physical trauma causing injury or death (i.e., typical traffic accidents).

4.3.4 Air Quality and Noise

The assessment of air quality impacts considered air pollutant emissions from normal facility operations associated with each alternative. Atmospheric dispersion of pollutant emissions from construction activities (e.g., engine exhaust and fugitive dust emissions), operations, and maintenance activities were estimated with conventional modeling techniques, such as those included in the EPA's SCREEN3 and Industrial Source Complex Short Term models (EPA 1995b-c). The estimated concentrations of these pollutants at facility boundaries were compared with existing air quality standards for criteria pollutants or with guidelines for pollutants that do not have corresponding standards.

Although noise impacts from facility construction and operations could occur during the implementation of any alternative, the extent of these impacts cannot be determined until the facility locations are known. Implementation of a management alternative might involve a variety of potentially noise-emitting equipment and operations. Examples include earthmoving and erecting equipment during construction, and process equipment, emergency generators, and both on-site and off-site traffic during operations. Although some sensitive receptors might be affected by the noise, the specific equipment to be used during the construction and operation of facilities has not been determined, and facility and receptor locations are unknown. These considerations will be addressed in subsequent Phase II analyses and NEPA reviews associated with the construction and operation of facilities.

4.3.5 Water and Soil

Potential impacts on surface water, groundwater, and soil were evaluated for facility construction, normal operations, and potential accidents. Methods of quantitative impact analyses for actual and representative sites are described in the following paragraphs. Because site-specific parameters are needed to quantify impacts, the PEIS provides only a qualitative discussion of impacts for activities assumed to occur in generic environmental settings (i.e., discussion of non-site-specific parameters such as water use, effluent volumes, paved areas, and excavation volumes).

For surface water, impacts were assessed in terms of runoff, floodplain encroachment, and water quality. Changes in runoff were assessed by comparing runoff depths predicted for existing conditions at actual or representative sites with runoff depths predicted for the modified conditions. The main inputs to the model were the paved area that would result from construction of new facilities, the total area available, and the approximate distribution of pavement, forests, and pasturelands at actual or representative sites. Floodplain encroachment was assessed by comparing simulated water depths in nearby rivers for existing conditions with those for modified flows. Inputs to the floodplain assessment model included estimated facility effluent volumes and estimates of flow volumes, channel shapes, cross-sectional areas, and water velocities in actual or representative nearby rivers. Water quality impacts were estimated by using the proposed drinking water standard of 20 μg/L (EPA 1996) as a guideline. Where data were unavailable, assessment models that account for the types of contaminants and dilution estimates for the surface water features were used to estimate surface water conditions.

Potential impacts on groundwater were assessed in terms of changes in recharge to underlying aquifers, depth to groundwater, direction of groundwater flow, and groundwater quality. Changes to recharge of groundwater were evaluated by comparing the increase in impermeable area produced by construction and operations with the recharge area available at actual or representative sites. Impacts on the depth to groundwater were evaluated by performing groundwater simulations for existing and modified conditions at the sites. Changes in the direction of groundwater flow were evaluated by examining the changes in water levels produced by the increased water demand. A model that considers movement, dispersion, adsorption, and decay of the contaminant source material over time was used to estimate migration of contaminants from source areas to the groundwater (i.e., groundwater quality). Details of the model are provided in Tomasko (1997).

Potential impacts to soil were assessed in terms of changes in topography, permeability, quality, and erosion potential. Erosion potential was evaluated by comparing soil removal rates at actual or representative sites with those for modified conditions using wind and water erosion models. Changes in topography were assessed by evaluation of excavation volumes required for facility construction. Changes in soil quality were evaluated on the basis of the amounts of contaminants deposited as a result of certain activities. No standard is available for limiting soil concentrations of uranium; a health-based guideline value of 230 μg/g (EPA 1995a), applicable for residential settings, was used as a guideline for comparison in the PEIS.

4.3.6 Socioeconomics

Potential impacts on socioeconomic conditions were considered during construction and operations of each facility. The analysis estimated these impacts within the ROIs around existing facilities and at representative or generic sites for facilities not yet sited. The analysis used annual material and labor expenditure data and detailed economic data describing the local industrial base and the proportion of procurement and wage and salary expenditures likely to occur in the local economy. These data were used to determine the direct (on-site) and indirect (off-site) impacts on employment and income. This information was then combined with additional demographic and local jurisdictional data to calculate the impact of each facility on population in-migration, local housing demand, and local public finances. Because the nature of local socioeconomic conditions was not known for the generic sites, the analysis of impacts for these sites was limited to the presentation of direct (on-site) employment and income impact of each facility.

4.3.7 Ecology

Potential impacts on ecological resources were assessed for terrestrial and aquatic biota, including impacts on vegetation and wildlife, wetlands, and federal- and state-listed threatened and endangered species. Where possible, the impact analysis focused on the radiological and chemical toxicity effects to biota resulting from exposure to uranium compounds and HF. Physical disturbances to biota and habitats were also evaluated. The general guidelines used to assess impacts of habitat loss and wildlife disturbance were as follows: (1) negligible to low impacts, corresponding to less than 10 acres of required land; (2) moderate impacts, corresponding to between 10 and 100 acres of required land; and (3) potential large impacts, corresponding to greater than 100 acres of required land. The potential for impacts to wetlands and federal- and state-listed threatened or endangered species is a site-specific consideration, and it would be determined in Phase II analyses and NEPA reviews.

4.3.8 Waste Management

Wastes generated during the management and use of depleted UF_6 have been subdivided into the following categories: radioactive waste (LLW and LLMW), nonradioactive hazardous and toxic waste, and nonhazardous, nonradioactive waste (solid waste and wastewater). Potential impacts on the various waste management facilities were evaluated by comparing current treatment capacities in existence at these facilities and within the DOE system with the additional waste management demands estimated for the different PEIS alternatives. Where new waste management facilities would be needed, the analysis considered the impacts from construction of such facilities. Also addressed were impacts from storing treated or untreated waste and impacts from packaging or handling the treated waste in preparation for disposal.

In the future, it is possible that waste generated during UF_6 management activities may be considered DOE waste, or it may be considered commercial waste, depending on whether the facilities are owned and/or operated by the federal government or the private sector. For purposes of comparison in the PEIS, estimated waste generation rates for the alternative management strategies have been compared to DOE waste generation rates over the same time periods.

4.3.9 Resource Requirements

The alternative management strategies considered in the PEIS would require the use of resources, including energy and materials, in at least one of the component steps. Evaluation of resource requirements in the PEIS considered construction materials that could not be recovered or recycled, radioactive materials that could not be decontaminated, and materials consumed (e.g., miscellaneous chemicals). Use of energy sources was considered, as well as use of uncommon materials with small reserves. Given the uncertainty associated with some key components of the management alternatives, such as final facility design and siting, this evaluation relied largely on a qualitative assessment to provide a sense of the amount of resources required and how these quantities would compare with the total available resources, either locally or nationally.

4.3.10 Land Use

For activities occurring at the current storage sites, the evaluation of potential land-use impacts associated with alternative management strategies was based on estimates of land area required and potential incompatibility with existing land-use patterns. The land required under alternatives with known site locations was calculated as a percent of existing or available land. The analysis considered the potential for alternative management strategies to result in land conversion, land-use conflicts, and impacts to surrounding lands.

The determination of potential land-use conflicts and traffic flow problems is a site-specific consideration. However, for purposes of analysis in this PEIS, general criteria for estimation of impacts were as follows: land-use requirement of less than 50 acres corresponds to negligible impacts, land-use requirement of between 50 and 200 acres corresponds to potential moderate impacts, and land-use requirement of greater than 200 acres corresponds to potential large impacts. The actual potential for land conversion in conflict with existing land-use plans and controls and/or traffic flow problems will be determined during the Phase II analyses and NEPA reviews.

4.3.11 Cultural Resources

Potential impacts to cultural resources could result from the construction of facilities for all of the alternatives considered in this PEIS. Possible impacts would include the disturbance of properties (e.g., archaeological sites or historic structures) eligible for the *National Register of Historic Places*, visual impacts to the environmental setting of an eligible property, or reduced access to a traditional use area (such as a cemetery or a resource for Native Americans). Differences in the land area required for each option would not affect the impact potential because important cultural resources are not equally distributed. Only limited impact evaluation was possible because specific sites have not been chosen for activities other than continued cylinder storage and cylinder preparation. Site-specific evaluation would be conducted during the Phase II analyses and NEPA reviews.

4.3.12 Environmental Justice

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," was issued by President Clinton in February 1994 and directs federal agencies to incorporate environmental justice into all agency missions (U.S. President 1994). Under Executive Order 12898, federal agencies are directed to identify and address, as appropriate, high and adverse human health or environmental effects caused by agency programs, policies, or actions that unfairly or "disproportionately" impact minority or low-income populations. Guidance for environmental justice considerations in NEPA has been developed by the Council on Environmental Quality (1997), EPA (1998), and DOE (1995d). A determination of the potential for a given project or action to result in impacts is based on an examination of the composition of the population residing within a defined zone of impact — for this analysis, a 50-mile (80-km) radius around each current storage site.

The environmental justice analysis employed a two-step process. In the first step, geographic areas associated with each affected region that might experience high and adverse impacts were examined; the purpose of this step was to determine if any of these areas would contain disproportionately high percentages of low-income or minority populations compared with the state(s) that contain the affected regions. In the second step, potential impacts were examined to determine if they would be high and adverse with regard to the total population. The analysis emphasized human health impacts — notably those resulting from radioactive and chemical releases — but also considered other technical areas that might affect low-income or minority populations. Environmental justice concerns were identified if an area was disproportionately either minority or low-income and if any impact was high and adverse.

4.3.13 Cumulative Impacts

Cumulative impacts are those that would result from the incremental impacts of an action (in this case, depleted UF_6 management alternatives) when added to other past, present, and reasonably foreseeable future actions. Both Council on Environmental Quality regulations (40 CFR 1508.7) and DOE regulations for implementing NEPA (10 CFR Part 1021) require the assessment of cumulative impacts because significant impacts can result from several actions that considered individually may be quite small.

The cumulative impact analysis was conducted by examining those impacts resulting from depleted UF_6 management activities that would occur at the three current storage sites (Paducah, Portsmouth, and K-25). The impacts from these activities (continued cylinder storage and cylinder preparation) were then added to the impacts of other past, present, and reasonably foreseeable future actions to assess potential cumulative impacts at the three sites.

The cumulative impacts of conversion, long-term storage, and disposal activities could not be determined because specific sites and technologies have not been designated for these options. Further analyses of cumulative impacts would be performed as required by NEPA and DOE regulations for any technology or siting proposals that would involve these facilities.

4.4 UNCERTAINTY IN ESTIMATED IMPACTS

Estimating environmental impacts for alternative approaches to depleted UF_6 management is subject to considerable uncertainty. This uncertainty is a consequence primarily of the preliminary nature of facility designs, the unknown location of future facilities, and the characteristics of the methods used to estimate impacts. To account for this uncertainty, the impact assessment was designed to ensure — through uniform and careful selection of assumptions, models, and input parameters — that impacts would not be underestimated and that relative comparisons among the alternatives would be meaningful. This was accomplished by uniformly applying common assumptions to each alternative and by choosing assumptions intended to produce conservative estimates of impacts — that is, assumptions that would lead to overestimates of the expected impacts. Although there would be some uncertainty in the estimates of the absolute magnitude of impacts, a uniform approach to impact assessment should enhance the ability to make valid comparisons among alternatives.

5 ENVIRONMENTAL IMPACTS OF ALTERNATIVES

Potential impacts to workers, members of the general public, and the environment were estimated for each of the alternative management strategies considered in this PEIS. This chapter presents those impacts associated with the management of the depleted UF_6 cylinder inventory generated by DOE prior to the formation of USEC in July 1993. The potential impacts associated with the management of USEC-generated cylinders that became the responsibility of DOE in May and June of 1998 are presented in Chapter 6. The general assessment methodologies and major assumptions used to estimate the impacts presented in this chapter are described in Chapter 4, with additional detailed methodology information provided in Appendix C.

Each of the PEIS alternatives is composed of combinations of several activities (see Chapter 2 and Figure 2.1). These management activities are addressed in detail in Appendices D through K:

- Appendix D — Environmental Impacts of Continued Cylinder Storage at Current Storage Sites
- Appendix E — Environmental Impacts of Options for Preparing Cylinders for Shipment or Long-Term Storage
- Appendix F — Environmental Impacts of Options for Conversion of UF_6 to Oxide or Metal
- Appendix G — Environmental Impacts of Options for Long-Term Storage as UF_6 and Uranium Oxide
- Appendix H — Environmental Impacts of Options for the Manufacture and Use of Uranium Oxide and Uranium Metal
- Appendix I — Environmental Impacts of Options for Disposal of Oxide
- Appendix J — Environmental Impacts of Transportation of UF_6 Cylinders, Uranium Oxide, Uranium Metal, and Associated Materials
- Appendix K — Parametric Analysis: Environmental Impacts for Processing Less than the Total Depleted UF_6 Inventory

Each appendix provides a discussion of the types of activities that would occur, the representative technologies and facilities considered, and the estimated environmental impacts associated with each option.

The potential environmental impacts assessed for this PEIS were determined by combining the impacts associated with each of the individual activities necessary to implement each alternative (as shown in Figures 2.1 through 2.7). Where appropriate, the impacts are presented as ranges, which account for differences in both the possible options and technologies that could be used and the effects that different environmental settings might have on the estimated environmental impacts. The discussion in this chapter focuses on the most significant issues and potential environmental impacts. Additional discussion of the analyses supporting the impacts reported here is presented in Appendices D through K.

Because sites for new facilities will be selected in Phase II of the Depleted Uranium Hexafluoride Management Program, the potential impacts presented for alternatives other than the no action alternative include a mixture of site-specific impacts and impacts calculated for representative or generic environmental settings. The level of analysis conducted depended on the specific activity considered. Continued cylinder storage and cylinder preparation activities would take place at the three current cylinder storage sites (Paducah, Portsmouth, and K-25). Potential impacts of these activities were thus assessed on a site-specific basis. Potential impacts of conversion and long-term storage (in buildings, vaults, and yards) were assessed for representative settings, and potential impacts of manufacture and use, long-term storage in a mine, and disposal were evaluated for generic settings (see Chapters 3 and 4 for descriptions of the environmental settings). Subsequent analysis with more site-specific environmental considerations will be performed during the Phase II analyses and NEPA reviews, as appropriate.

To provide a conservative analysis of transportation and construction impacts, it was assumed that facilities for conversion, long-term storage, manufacture and use, and disposal would be located at separate sites other than the three current storage sites. This approach was intended to provide a conservative estimate of the total impacts associated with the alternatives because it would require the transportation of materials between sites and the construction of new facilities and supporting infrastructure. The transportation impacts were analyzed using representative route characteristics for a range of possible distances between sites. Colocating facilities is consistent with Public Law 105-204 and DOE's current plan. Colocation could reduce or even eliminate the transportation of uranium and associated materials and possibly reduce the amount of land and construction activities required. The impacts of colocating facilities are discussed in Section 5.8.3.

For all alternatives, potential environmental impacts were evaluated for the period 1999 through 2039. For the continued storage component of all alternatives and for the disposal alternative, potential long-term impacts were also evaluated, primarily with respect to groundwater contamination. Because depleted uranium would require management beyond 2039, a discussion of potential actions and impacts that might occur beyond that date (i.e., life-cycle impacts) is provided in Section 5.9. Detailed analysis was generally not conducted beyond 2039 because actions and impacts beyond that time are highly uncertain, and thus decisions related to them are not ready to be made at this time.

5.1 NO ACTION ALTERNATIVE

Under the no action alternative, depleted UF_6 cylinder storage would continue at each of the three current storage sites indefinitely. The potential environmental impacts were estimated through the year 2039. In addition, the long-term impacts from potential groundwater contamination were estimated. A detailed discussion of site-specific impacts of continued cylinder storage at each of the three current storage sites is presented in Appendix D. This section provides a summary of those impacts.

The potential environmental impacts of the no action alternative were based on the cylinder management activities that will take place at the sites in the future. Current detailed cylinder management plans extend through the year 2002 (LMES 1997i). The ongoing and planned activities are designed to ensure continued safe storage of cylinders. These activities include cylinder inspections, cylinder yard upgrades, cylinder painting, and cylinder maintenance and repair activities. Beyond 2002, a set of cylinder management assumptions was needed to define the activities that would probably occur at the sites through 2039 so that the potential impacts could be estimated. It was assumed that the types of activities that would occur generally would be similar to those that are now ongoing or planned (Parks 1997). The assumptions were chosen in such a way that the impacts would be overestimated rather than underestimated.

Specifically, the activities assumed to occur at the sites during the no action alternative include a comprehensive cylinder monitoring and maintenance program, with routine cylinder inspections, ultrasonic thickness testing of cylinders, radiological surveys, cylinder painting to prevent corrosion, cylinder yard surveillance and maintenance, construction of four new or improved storage yards at the Paducah site and one at K-25 site between 1999 and 2002, and relocation of some cylinders at all three sites. Cylinders were assumed to be painted every 10 years. These activities are described in greater detail in Appendix D.

An important issue with respect to potential environmental impacts of continued cylinder storage is the expected condition of the cylinders over time. During storage that has been ongoing from the mid-1950s to the present, previous substandard storage conditions have led to corrosion and pitting of many cylinder surfaces, and eight breached cylinders have been identified and repaired. These cylinders had holes in their walls in sizes ranging from very small (1/16 in. [0.16 cm]) to 15 in. (38 cm) in diameter. Corrosion of the cylinders in the past occurred while many of the cylinders were stored in substandard cylinder yard conditions. In addition, cylinders were not routinely painted to control corrosion. An intensive program has been ongoing for several years to improve the storage conditions of the cylinders. Some storage yards have been reconstructed, and new storage yards with concrete bases and controlled runoff have been added. Many cylinders have been relocated to better storage conditions. The improved storage yard conditions are expected to decrease corrosion rates.

In addition, the cylinder painting program is expected to control external corrosion of the cylinders (Pawel 1997).

For assessment of the no action alternative, it was assumed that the cylinder maintenance and painting program would protect the cylinders from further corrosion. The cylinders would continue to corrode at the historical rates until painted. Some future cylinder breaches were assumed to occur from handling damage after the initial painting. Although unlikely, for analysis purposes these breaches were assumed to go undetected for 4 years (the inspection interval for most cylinders) and to release some uranium and HF to the environment. The number of future cylinder breaches through 2039 was estimated to be 36 at the Paducah site, 16 at the Portsmouth site, and 7 at the K-25 site (see Appendix B).

Although it is expected that cylinder maintenance and painting will control cylinder corrosion, there are some uncertainties concerning the future condition of the cylinders. Current estimates suggest a paint effectiveness of at least 10 years (Pawel 1997). However, it is possible that the cylinders would not be painted every 10 years because of budget or other considerations. In addition, it is possible that the paint might not be effective for 10 years. Because of these uncertainties, an assessment was also conducted on the basis of the assumption that external corrosion would not be halted by improved storage conditions, cylinder maintenance, and painting. Assuming that corrosion rates would continue at the historical rate (poor storage conditions and no routine painting), many more breaches would be expected to occur over time at the three storage sites. The total number of breaches through 2039 was estimated to be about 440 at Paducah, 70 at Portsmouth, and 210 at K-25 (see Appendix B). The results of this assessment were used to provide an estimate of the earliest time when continued cylinder storage could begin to raise regulatory concerns if external corrosion of the cylinders was not controlled.

5.1.1 Human Health and Safety

Under the no action alternative, potential impacts to human health and safety could result from facility operations during both routine conditions and accidents. In general, the impacts during normal facility operations at all sites would be limited to workers directly involved in handling cylinders. Under accident conditions, the health and safety of both workers and members of the general public around the sites could potentially be affected.

5.1.1.1 Normal Facility Operations

5.1.1.1.1 Workers

Cylinders containing depleted UF_6 emit low levels of gamma radiation. Involved workers would be exposed to this radiation when working near cylinders, such as during routine cylinder monitoring and maintenance activities, cylinder relocation and painting, and when patching or repairing cylinders. It was estimated that a total of about 60 cylinder yard workers (on average) would be required at the three current storage sites (30 at Paducah, 16 at Portsmouth, and 13 at K-25). These workers would be trained to work in a radiation environment, they would use protective equipment as necessary, and their radiation exposure levels would be measured and monitored by safety personnel at the sites. Radiation exposure of workers is required by law to be maintained ALARA.

The radiation exposure of involved workers (cylinder yard workers) in future years through 2039 was estimated to be well within public health standards (10 CFR Part 835). If the same 60 workers conducted all cylinder management activities, the average annual dose to individual involved workers was estimated to be about 740 mrem/yr at Paducah, 600 mrem/yr at Portsmouth, and 410 mrem/yr at K-25. Worker doses are required by health regulations to be maintained below 5,000 mrem/yr (10 CFR Part 835). The estimated future doses did not account for standard ALARA practices that would be used to keep the actual doses as far below the limit as practicable. Thus, the future doses to workers would be expected to be less than those estimated because of the conservatism in the assumptions and models used to generate the estimates. In fact, from 1990 through 1995, the average measured doses to cylinder yard workers ranged from about 16 to 56 mrem/yr at Paducah, 55 to 196 mrem/yr at Portsmouth, and 32 to 92 mrem/yr at K-25 (Hodges 1996). For comparison, radiation doses from background radiation and some common activities are given in Table 4.4.

The total dose to all involved workers at the three current storage sites from 1999 through 2039 was estimated to be about 1,500 person-rem (the dose to noninvolved workers is negligible [i.e., less than 1%] compared to the dose to involved workers). This dose would be distributed among all of the workers involved with cylinder activities over the 41-year period. About 60 workers would be required each year; however, the number of different individuals involved over the period would probably be much greater than this because workers could be rotated to different jobs and could change jobs. This level of exposure was estimated to potentially result in about 1 LCF among all the workers exposed, in addition to the cancer cases that would result from all other causes.

Impacts to involved and noninvolved workers from exposure to chemicals during normal operations are not expected. The workplace would be monitored to ensure that airborne chemical concentrations were within applicable health standards that are protective of human health and safety. If planned work activities were likely to expose involved workers to chemicals, they would be provided with appropriate protective equipment as necessary. The potential chemical exposures of noninvolved workers from any airborne releases during normal operations were estimated to be below levels expected to cause adverse effects (the hazard indices were estimated to be less than 0.002 for noninvolved workers at all three sites).

5.1.1.1.2 General Public

Potential health impacts to members of the general public could occur if material released from breached cylinders entered the environment and was transported from the sites through the air, surface water, or groundwater. Off-site releases of uranium and HF are possible from breached cylinders. However, the predicted off-site concentrations of these contaminants in the future were estimated to be much less than levels expected to cause adverse effects. Potential exposures of members of the general public would be well within public health standards. No adverse effects (LCFs or chemical effects) were estimated to occur among the general public residing within 50 miles (80 km) of each site from depleted UF_6 management activities.

If all the uranium and HF assumed to be released from breached cylinders through 2039 were dispersed from the sites through the air, the total radiation dose to the general public (all persons within 50 miles [80 km]) was estimated to be less than 0.38 person-rem over the period 1999 through 2039 (all three sites combined). This level of exposure would most likely result in zero cancer fatalities among members of the general public. For comparison, the average radiation dose from natural background radiation to a single person in 1 year is about 0.36 person-rem (360 mrem). The maximum radiation dose to an individual near any one of the sites was estimated to be less than about 0.2 mrem/yr, well within health standards. Radiation doses to the general public are required by health regulations to be maintained below 10 mrem/yr from airborne sources (40 CFR Part 61) and below a total of 100 mrem/yr from all sources combined (DOE Order 5400.5). If an individual were to receive the maximum estimated dose every year (1999–2039), the total dose would be about 8 mrem, resulting in an additional chance of dying from a latent cancer of about 1 in 200,000. No noncancer health effects from exposure to airborne uranium and HF releases would be expected — the estimated hazard index for a maximally exposed individual was estimated to be less than 0.1 at all three sites. This means that the total exposure would be at least 10 times less than exposure levels that might cause adverse effects.

The material released from breached cylinders could also potentially be transported from the sites in water, either in surface water runoff or by infiltrating the soil and contaminating groundwater. Members of the general public potentially could be exposed if this contaminated surface water or groundwater were used as a source of drinking water. The results of the surface water and groundwater analyses indicate that the maximum estimated uranium concentrations in surface water accessible to the general public and in groundwater beneath the sites would be less than the proposed EPA drinking water standard of 20 μg/L (EPA 1996) used as a guideline at all three sites (see Sections 5.1.4.1 and 5.1.4.2, respectively). Drinking water standards, meant to apply to water "at the tap" of the user, are set at levels protective of human health.

If a member of the public were to use contaminated water at the maximum concentrations estimated, adverse effects would be unlikely. Assuming a member of the general public used contaminated surface water or groundwater as their primary water source, the maximum radiation dose in the future was estimated to be less than 0.5 mrem/yr at each site. The corresponding risk to this individual of dying from a latent cancer would be less than 1 in 1 million per year. Noncancer health effects from exposure to possible water contamination would not be expected — the estimated hazard index for an individual assumed to use the groundwater was less than 0.2. This means that the total exposure would be 5 times less than the exposure that might cause adverse effects.

If no credit is taken for reduced cylinder corrosion rates from cylinder maintenance and painting activities, the groundwater analysis indicates that the uranium concentration in groundwater at the three sites could exceed 20 μg/L sometime in the future (see Section 5.1.4.2). In such a case, mitigative measures, such as treatment of the water or supplying an alternative source of water, might be required to ensure the safety of those potentially using the water.

5.1.1.2 Facility Accidents

5.1.1.2.1 Physical Hazards (On-the-Job Injuries and Fatalities)

Accidents occur in all work environments. In 1994, about 5,000 people in the United States were killed in accidents while at work, and approximately 3.5 million work-related injuries were reported (National Safety Council 1995). Although all work activities would be conducted in as safe a manner as possible, there is a chance that workers could be accidentally killed or injured under the no action alternative, unrelated to any radiation or chemical exposures.

The numbers of accidental worker injuries and fatalities that might occur from 1999 through 2039 were estimated. The estimates were based on the number of workers required over this period and on the historical accident fatality and injury rates in similar types of industries (see Appendix D, Section D.2). It was estimated that a total of about 0.1 accidental fatality (about 1 chance in 10 of a single fatality) might occur at the three sites over the 41-year period. Similarly, a total of about 140 accidental injuries (defined as injuries resulting in lost workdays) was estimated at the three sites combined. These rates would not be unique to the activities required for the no action alternative, but would be typical of any industrial project of similar size and scope.

5.1.1.2.2 Accidents Involving Releases of Radiation or Chemicals

Under the no action alternative, accidents are possible that could release radiation and chemicals from cylinders. A wide range of different types of accidents was evaluated at each of the three current storage sites. The accidents included those initiated by operational events, such as equipment or operator failure; external hazards, such as aircraft crashes; and natural phenomena, such as earthquakes. The assessment considered accidents ranging from those that would be reasonably likely to occur (one or more times in 100 years on average) to those that would be extremely rare (estimated to occur less than once in 1 million years on average).

The accidents of most concern at the sites are accidents that could cause a release of UF_6 from cylinders. In a given accident, the amount potentially released would depend on the severity of the accident and the number of cylinders involved. Following a release, the UF_6 could combine with moisture in the air, forming gaseous HF and uranyl fluoride, a soluble solid in the form of small particles. The depleted uranium and HF could be dispersed downwind, potentially exposing workers and members of the general public living near the sites to radiation and chemical effects. The workers considered in the accident assessment were those noninvolved workers not immediately in the vicinity of the accident; fatalities and injuries among involved workers are possible for severe accidents (see Section 4.3.2.1).

The estimated consequences of cylinder accidents are summarized in Table 5.1 for chemical effects and in Table 5.2 for radiation effects. The impacts are the maximums estimated for any of the three current storage sites (site-specific impacts are presented in Appendix D). The impacts are presented separately for accidents considered likely and for those rare, low-probability accidents that were estimated to result in the largest potential impacts. Although other accidents were evaluated (see Appendix D, Section D.2.2), the estimated consequences of other accidents at all three sites would be less than those summarized in the tables. The estimated consequences are conservative in nature because they were based on the assumption that the wind would be blowing in the direction of the greatest number of people at the time of the accident and that weather conditions would limit dispersion in the air, so that high concentrations would occur. In addition, the effects of protective measures, such as evacuation, were not considered.

Chemical Effects. The potential likely accident (defined as an accident that is estimated to occur one or more times in 100 years) that would cause the largest chemical health effects is the failure of a corroded cylinder spilling part of its contents under dry weather conditions. Such an accident could occur, for example, during cylinder handling activities. It was estimated that about 24 lb (11 kg) of UF_6 could be released in such an accident. The potential consequences from this type of accident would be limited to on-site workers. The off-site concentrations of HF and uranium were calculated to be less than the levels that would cause adverse effects from exposure to these chemicals, so that zero adverse effects were estimated to occur among members of the general public. If this accident did occur, it was estimated that up to 70 noninvolved workers might experience potential adverse effects from exposure to HF and uranium (mostly mild and transient effects, such as respiratory irritation or temporary decrease in kidney function). It was estimated that 3 noninvolved workers might experience potential irreversible adverse effects (such as lung or kidney damage). The number of fatalities following an HF or uranium exposure is expected to be somewhat less than 1% of the number of potential irreversible adverse effects (Policastro et al. 1997). Therefore, no fatalities would be expected. In nearly 40 years of cylinder handling activities, no accidents involving releases from cylinders containing solid UF_6 have occurred that have caused diagnosed irreversible adverse effects among workers.

For assessment purposes, the estimated frequency of a corroded cylinder spill accident was assumed to be about once in 10 years. Therefore, over a 41-year period, about four such accidents

TABLE 5.1 Estimated Consequences of Chemical Exposures for Accidents under the No Action Alternative[a]

Receptor[b]	Accident Scenario	Site	Accident Frequency Category[c]	Effect[d]	Consequence[e] (persons affected)
			Likely Accident(s)		
General public	Corroded cylinder spill, dry conditions	All sites	L	Adverse effects	0
	Corroded cylinder spill, dry conditions	All sites	L	Irreversible adverse effects	0
	Corroded cylinder spill, dry conditions	All sites	L	Potential fatalities	0
Noninvolved Workers	Corroded cylinder spill, dry conditions	K-25	L	Adverse effects	70
	Corroded cylinder spill, dry conditions	K-25	L	Irreversible adverse effects	3
	Corroded cylinder spill, dry conditions	K-25	L	Potential fatalities	0
			Low Frequency-High Consequence Accident(s)		
General public	Vehicle-induced fire, 3 full 48G cylinders	Paducah	EU	Adverse effects	1,900
	Corroded cylinder spill, wet conditions – water pool	Portsmouth	EU	Irreversible adverse effects	1
	Corroded cylinder spill, wet conditions – water pool	Portsmouth	EU	Potential fatalities	0
Noninvolved Workers	Vehicle-induced fire, 3 full 48G cylinders	Portsmouth	EU	Adverse effects	1,000
	Corroded cylinder spill, wet conditions – water pool	Paducah	EU	Irreversible adverse effects	300
	Corroded cylinder spill, wet conditions – water pool	Paducah	EU	Potential fatalities	3

[a] The accidents listed are those estimated to result in the greatest impacts among all the accidents considered at all three sites. The site-specific impacts for a range of accidents at each of the three current storage sites are listed in Appendix D. The consequences are different at each site because of differences in the worker and public population distributions around the sites.

[b] Noninvolved workers are persons working at the site but not involved in handling of materials. Depending on the circumstances of the accident, injuries and fatalities among involved workers are possible for all accidents.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/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] Potential adverse effects include exposures that could result in mild and transient injury, such as respiratory irritation. Potential irreversible adverse effects include exposures that could result in permanent injury (e.g., impaired organ function) or death. The majority of the adverse effects would be mild and temporary in nature. It is estimated that less than 1% of the predicted potential irreversible adverse effects would result in fatalities (see text).

[e] The consequence is expressed as the maximum number of individuals with a predicted exposure level sufficient to cause the corresponding health endpoint. The estimated consequences were based on the assumption that the meteorological conditions would be F stability with 1 m/s wind speed, considered to be the worst conditions, and that the wind would be blowing in the direction of the highest worker or public population density.

TABLE 5.2 Estimated Consequences from Radiation Exposures for Accidents under the No Action Alternative[a]

Receptor[b]	Accident Scenario	Site	Accident Frequency Category[c]	MEI Dose (rem)	MEI Lifetime Risk of LCF	Population Dose (person-rem)	Population Number of LCFs
			Likely Accident(s)				
General public	Corroded cylinder spill, dry conditions	K-25	L	0.003	1×10^{-6}	0.43	0.0002
Noninvolved Workers	Corroded cylinder spill, dry conditions	Portsmouth	L	0.077	3×10^{-5}	2.2	0.0008
			Low Frequency-High Consequence Accident(s)				
General public	Vehicle-induced fire, 3 full 48G cylinders	Paducah	EU	0.015	7×10^{-6}	28	0.01
Noninvolved Workers	Vehicle-induced fire, 3 full 48G cylinders	K-25	EU	0.02	8×10^{-6}	16	0.006

[a] The accidents listed are those estimated to have the greatest impacts among all accidents considered at all three sites. The impacts for a range of accidents at each of the three current storage sites are listed in Appendix D. The estimated consequences were based on the assumption that the wind would be blowing in the direction of the highest worker or public population density and that weather conditions limited dispersion.

[b] Noninvolved workers are persons working at the site but not involved in handling of materials. Depending on the circumstances of the accident, injuries and fatalities among involved workers are possible for all accidents.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/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).

would be expected. The accident risk (defined as consequence times probability) would be about 280 workers with potential adverse effects and 12 workers with potential irreversible adverse effects over the period 1999 through 2039. The number of workers actually experiencing these effects would probably be considerably less, depending on the actual circumstances of the accidents and the individual chemical sensitivity of the workers. In previous accidental exposure incidents involving liquid UF_6 in gaseous diffusion plants, a few workers have been exposed to amounts of uranium estimated to be approximately three times the guidelines used for assessing irreversible adverse effects in this PEIS, and none actually experienced irreversible adverse effects (McGuire 1991).

Accidents that are less likely to occur could have higher consequences. The potential cylinder accident at any of the sites estimated to result in the greatest total number of adverse chemical effects is an accident involving three cylinders in a fire caused by an on-site vehicle accident (although more cylinders than three might be affected by a fire, three was the most likely number based on estimates of the fuel available from a truck). If this accident occurred, it was estimated that up to 1,900 members of the general public and 1,000 noninvolved workers might experience adverse effects from HF and uranium exposure (mostly mild and transient effects, such as respiratory irritation or temporary decrease in kidney function). This accident is considered extremely unlikely, estimated to occur between once in 10,000 years and once in 1 million years. If the frequency is assumed to be once in 100,000 years, the accident risk over the period 1999 through 2039 would be less than 1 adverse effect for both workers and members of the general public.

The potential cylinder accident estimated to result in the largest total number of irreversible adverse effects is a corroded cylinder spill under wet conditions, where the UF_6 was assumed to be released into a pool of standing water. This accident is also considered extremely unlikely, expected to occur between once in 10,000 years and once in 1 million years. If this accident occurred, it was estimated that about 1 member of the general public and 300 noninvolved workers might experience irreversible adverse effects from HF and uranium exposure (such as lung damage). The number of fatalities would be somewhat less than 1% of the estimated number of potential irreversible adverse effects (Policastro et al. 1997). Thus, no fatalities would be expected among the general public, although 3 fatalities could occur among noninvolved workers (1% of 300). If the frequency of this accident is assumed to be once in 100,000 years, the accident risk over the period 1999 through 2039 would be less than 1 (0.1) irreversible adverse health effect among workers and the general public, combined.

Radiation Effects. Potential cylinder accidents could release uranium, which is radioactive in addition to being chemically toxic. The potential radiation exposures of members of the general public and noninvolved workers were estimated for the same cylinder accidents discussed for chemical effects (Table 5.2). For all cylinder accidents considered, the radiation doses from released uranium were estimated to be considerably below levels likely to cause radiation-induced effects among noninvolved workers and the general public, and below the 25-rem dose recommended by the NRC (1994a) for assessing the adequacy of protection of public health and safety from potential accidents.

For the corroded cylinder spill accident (dry conditions), the radiation dose to a maximally exposed member of the general public at any of the sites was estimated to be less than 3 mrem (lifetime dose), resulting in an increased risk of death from cancer of about 1 in 1 million. The total population dose to the general public within 50 miles (80 km) was estimated to be less than 1 person-rem, most likely resulting in zero LCFs. Among noninvolved workers, the dose to an MEI was estimated to be 77 mrem, resulting in an increased risk of death from cancer of about 1 in 30,000. The total dose to all noninvolved workers was estimated to be about 2.2 person-rem. This dose to workers was estimated to result in zero LCFs. The risk (consequence times probability) of additional LCFs among members of the general public and workers combined would be much less than 1 over the period 1999 through 2039.

The cylinder accident estimated to result in the largest potential radiation doses would be the accident involving three cylinders in a fire. For this accident, the radiation dose to a maximally exposed member of the general public was estimated to be about 15 mrem, resulting in an increased risk of death from cancer of about 1 in 150,000. The total population dose to the general public within 50 miles (80 km) was estimated to be 28 person-rem, most likely resulting in zero LCFs. Among noninvolved workers, the dose to an MEI was estimated to be about 20 mrem, resulting in an increased risk of death from cancer of about 1 in 100,000. The total dose to all noninvolved workers was estimated to be about 16 person-rem. This dose to workers was estimated to result in zero LCFs. The risk (consequence times probability) of additional LCFs among members of the general public and workers combined would be much less than 1 over the period 1999 through 2039.

5.1.2 Transportation

Continued cylinder storage under the no action alternative would potentially generate small amounts of LLW and LLMW during cylinder monitoring and maintenance activities. This material could require transportation to a treatment or disposal facility. Shipments would be made in accordance with all DOE and DOT regulations and guidelines. It was estimated that less than one waste shipment would be required each year. Because of the small number of shipments and the low concentrations of contaminants expected, the potential environmental impacts from these shipments would be negligible (see Appendix J).

5.1.3 Air Quality

Potential impacts to air quality for the no action alternative considered air pollutant emissions from continued cylinder storage activities, including construction of new yards (engine exhaust and particulate matter emissions [i.e., dust]), operations (cylinder painting and vehicle emissions), and HF emissions from breached cylinders. Atmospheric dispersion models were used to estimate the concentrations of criteria pollutants at the site boundaries. Criteria pollutants are those that have corresponding federal air quality standards — hydrocarbons (HC), CO, NO_x, sulfur oxides (SO_x), Pb, and PM_{10}. The site boundary concentrations were compared with existing air quality standards or with guidelines for pollutants that do not have corresponding standards. These standards and guidelines are given in Chapter 3. For the no action alternative, estimated concentrations of criteria pollutants and HF were all within applicable standards and guidelines. However, because potential PM_{10} emissions during construction activities were estimated to be very close to the standards, procedures to reduce these emissions might have to be implemented during construction.

In general, the highest levels of criteria pollutants would be generated by construction activities occurring at the Paducah and K-25 sites. Except for PM_{10}, the air concentrations of all criteria pollutants resulting from no action alternative activities would be less than 3% of the respective standards. Particulate matter emissions from construction could result in maximum 24-hour average PM_{10} concentrations just below the standards (about 90 to 95% of the standard value of 150 $\mu g/m^3$), although the estimated annual average concentrations would be lower (about 30 to 55% of the standard value of 50 $\mu g/m^3$). During actual construction, mitigative measures would be taken to reduce the generation of particulate matter, such as spraying the soil with water and covering the excavated soil. Such measures are commonly employed during construction but were not accounted for in the modeling done for the PEIS analysis. Currently planned construction activities for the no action alternative are limited to the first few years of operations (through 2002).

Operations activities would emit much lower concentrations of criteria pollutants than would construction activities (all lower than 0.3% of standards). Painting activities could generate hydrocarbon emissions. There is no explicit air quality standard for hydrocarbon emissions, but these emissions are associated with ozone formation. For each of the three current cylinder storage sites, hydrocarbon emissions from painting activities would be less than 1.2% of the hydrocarbon emissions from the entire surrounding county. Because ozone formation is a regional issue affected by emissions for an entire area, these small additional contributions to the county totals would be unlikely to substantially alter the ozone levels of the county.

Estimated annual average site boundary concentrations of HF from hypothetical cylinder breaches occurring under the no action alternative ranged from 0.01 to 0.08 $\mu g/m^3$ for the three sites. The States of Kentucky and Tennessee have HF air standards, whereas no federal or State of Ohio standards exist. The annual average HF concentration for the Paducah site was estimated to be less than 0.002% of the standard. The estimated maximum 24-hour average HF concentration for the K-25 site is 0.67 $\mu g/m^3$, which is about 23% of the State of Tennessee 24-hour average standard for HF (the HF standards for Tennessee are much lower than those for Kentucky).

If no credit is taken for corrosion reduction through painting and continued maintenance, and if storage is continued at the three current storage sites indefinitely, calculations indicate that breaches occurring at the K-25 site by around the year 2020 could result in maximum 24-hour average HF concentrations at the site boundaries equal to approximately 2.9 $\mu g/m^3$ (3.5 parts per billion [ppb]) (Tschanz 1997b). This level corresponds to the primary standard for the State of Tennessee. For comparison, the maximum estimated 24-hour average HF concentrations at the Paducah and Portsmouth sites through the year 2039 were estimated to be 2 and 0.6 $\mu g/m^3$, respectively. (The State of Kentucky primary standard for HF maximum 24-hour average is much higher, 800 μg/m^3; the State of Ohio does not have ambient air quality standards for HF.) Because of the ongoing painting and maintenance program, it is not expected that breaches occurring prior to 2039 would be sufficient to increase the HF concentrations above the applicable standards at any of the sites (Tschanz 1997a).

5.1.4 Water and Soil

Potential impacts on surface water, groundwater, and soil could occur during continued storage of the cylinders under the no action alternative. Important elements in assessing potential impacts for surface water include changes in runoff, floodplain encroachment, and water quality. Groundwater impacts were assessed in terms of changes in recharge to the underlying aquifers, depth to groundwater, direction of groundwater flow, and groundwater quality. Potential soil impacts considered were changes in topography, permeability, erosion potential, and soil quality.

For the no action alternative, very limited construction activity is planned, and that planned activity would occur in previously developed areas. Water use and waste water discharge would also be very limited. Therefore, the assessment area in which potentially important impacts might occur was determined to be quality of surface water, groundwater, and soil. The other potential impacts would all depend on changes in permeable land areas at the sites due to construction activities or on water use and effluent volumes.

The contaminant of concern for evaluating surface water, groundwater, and soil quality is uranium. Surface water and groundwater concentrations of contaminants are generally evaluated through comparison with the EPA MCLs, as given in *Safe Drinking Water Act* regulations (40 CFR Part 141), although these limits are only directly applicable "at the tap" of the water user. The proposed MCL for uranium is 20 μg/L (EPA 1996); this value has been used as a guideline for evaluating surface water and groundwater concentrations of uranium in this PEIS, although it is not directly applicable as a standard. There is also no standard available for limiting concentrations of uranium in soil; a health-based value of 230 μg/g (EPA 1995a), applicable for residential settings, has been used as a guideline for comparison in this PEIS.

The nearest surface waters to the current storage sites are Little Bayou Creek, Little Beaver Creek, and Poplar Creek for the Paducah, Portsmouth, and K-25 sites, respectively. These surface waters are tributaries to larger rivers at each of the sites; the larger rivers are used as drinking water sources. Because of very large dilution effects, even very high levels of contaminants in the nearest site surface waters would not be expected to cause levels exceeding guidelines at the drinking water intakes of the larger rivers.

Water use during construction activities would be 2 million and 0.8 million gal for the Paducah and K-25 sites, respectively. Maximum water use during operations would be 160,000, 60,000, and 32,000 gal/yr for the Paducah, Portsmouth, and K-25 sites, respectively.

5.1.4.1 Surface Water

Potential impacts on the nearest receiving water at each site (i.e., Little Bayou Creek, Little Beaver Creek, and Poplar Creek) were estimated for uranium released from hypothetical cylinder breaches occurring through 2039. The estimated maximum concentrations of uranium in these receiving waters were 0.3, 0.7, and 0.02 µg/L for the Paducah, Portsmouth, and K-25 sites, respectively. These concentrations are considerably below the 20 µg/L level used for comparison.

5.1.4.2 Groundwater

Potential impacts on groundwater quality from hypothetical releases of uranium from breached cylinders were also assessed. The maximum future concentrations of uranium in groundwater directly below the sites were estimated to be 6, 5, and 7 µg/L for the Paducah, Portsmouth, and K-25 sites, respectively. Assuming a rapid rate of uranium migration, these concentrations were estimated to occur sometime after the year 2070. Lower concentrations would occur if uranium migration through the soil was slower. The groundwater concentrations at all three sites were estimated to be considerably below the 20 µg/L level used for comparison.

Groundwater in the vicinity of the Paducah and Portsmouth sites is used for domestic and industrial supplies. Groundwater in the vicinity of the K-25 site discharges to nearby surface waters and is not known to be used as a domestic or industrial source. (See Chapter 3 for a discussion of existing groundwater quality at each of the sites.) At Paducah, a municipal water supply has been supplied by the Paducah site to residents having wells within an area of groundwater contaminated with trichloroethylene and technetium-99. At Portsmouth, sampling results indicate that residential water supplies have not been affected by site operations. Activities associated with the no action alternative would not affect migration of existing groundwater contamination or off-site water supplies.

If no credit is taken for corrosion reduction through cylinder painting and maintenance, and if storage is continued at the three current storage sites indefinitely, calculations indicate that uranium releases from future cylinder breaches occurring at the Paducah site prior to about the year 2020 could result in a sufficient amount of uranium in the soil column to increase the groundwater concentration of uranium to 20 µg/L in the future (about 2100). The cylinders would have to undergo uncontrolled corrosion (without painting and maintenance) until about 2050 at the Portsmouth site and until about 2025 at the K-25 site before the same groundwater concentration guideline of 20 µg/L would be a concern. The groundwater concentration would not actually reach 20 µg/L at these sites until about 2100 or later. Because of the ongoing painting and maintenance program, it is not expected that breaches occurring prior to 2039 would be sufficient to increase the groundwater concentration to 20 µg/L at any of the sites.

5.1.4.3 Soil

Potential impacts on soil that could receive contaminated rainwater runoff from the cylinder storage yards were estimated. The source was assumed to be uranium released from hypothetical breached cylinders. The estimated maximum soil concentrations were 1, 1, and 3 μg/g for the Paducah, Portsmouth, and K-25 sites, respectively. These concentrations are considerably below the 230 μg/g guideline used for comparison.

5.1.5 Socioeconomics

The potential socioeconomic impacts of construction and operational activities under the no action alternative would be low. Construction activities at the Paducah and K-25 sites would create short-term employment (30 direct jobs, 110 total jobs in the peak construction year); operational activities occurring at the three sites would create 110 direct jobs and 210 total jobs per year. Direct and total income from construction in the peak year would be $1.4 million and $3.5 million, respectively. During operations, direct and total income would be $5.1 million/yr and $6.7 million/yr, respectively.

The employment and income created in the ROIs for the three sites would represent a change of less than 0.005% of projected growth in these indicators of overall regional activity. The in-migration expected into each region with each activity would have only a low impact on regional population growth rates and would require less than 2% of vacant housing stock at each of the three sites. No significant impacts on local public finances would be expected.

5.1.6 Ecology

The no action alternative would have a negligible impact on ecological resources in the area of the three current storage sites. Very limited construction activity is planned, and the planned activities would all occur in previously developed areas. Thus, impacts on wetlands and federal- and state-protected species due to facility construction would also be negligible.

The assessment results indicate that impacts to ecological resources from facility operations would be negligible. Analysis of potential impacts was based on exposure of biota to airborne contaminants or contaminants released to soil, groundwater, or surface water. Predicted concentrations of contaminants in environmental media were compared to benchmark values of toxic and radiological effects (see Appendix C, Section C.3.3). At all three sites, soil, groundwater, and surface water concentrations would be considerably below levels harmful to biota.

5.1.7 Waste Management

Under the no action alternative, construction and operations at the current storage sites would generate relatively small amounts of LLW and LLMW. The volume of LLW generated by continued storage activities would represent less than 1% of the annual generation at each of the three sites.

The maximum annual amount of LLMW generation from stripping/painting operations at the Paducah site would generate about 20% of the site's total annual LLMW load, constituting a potential moderate impact on LLMW management. LLMW generation for the Portsmouth and K-25 sites would be less than 1% of site LLMW generation, resulting in negligible waste management impacts for these sites. The total volume of LLMW generated at all three sites would also be less than 1% of the projected annual DOE LLMW treatment volume (i.e., 68,000 m^3/yr; see Appendix C, Section C.10), so that the overall impact on waste management operations from the no action alternative would be negligible to low.

5.1.8 Resource Requirements

Construction and operation of facilities under the no action alternative would consume electricity, fuel, concrete, steel and other metals, and miscellaneous chemicals that are generally irretrievable resources. The total quantities of commonly used materials would be small compared to local sources and would not affect local, regional, or national availability of these materials. No strategic or critical materials are projected to be consumed during construction or operations. The anticipated utilities requirements would be within the supply capacities at each site. The required material resources during construction and operations at all three sites would be readily available.

5.1.9 Land Use

Very limited construction activity is planned under the no action alternative. For the Paducah site, only reconstruction of storage yards within the boundaries of existing yards is planned, so additional land clearing would not be necessary. For the K-25 site, construction of a new storage yard with an area of approximately 6.7 acres (2.7 ha) is planned, but this yard is expected to be located in an area already dedicated to similar use. No new construction is planned for the Portsmouth site. Therefore, impacts of the no action alternative with respect to land use would be none or negligible.

5.1.10 Cultural Resources

Under the no action alternative, impacts to cultural resources would not be likely at the Paducah or Portsmouth sites during continued cylinder storage. (See Chapter 3 for a discussion of cultural resources existing at the three storage sites.) The existing storage yards at Paducah are located in previously disturbed areas unlikely to contain cultural properties or resources listed on or eligible for the *National Register of Historic Places.* No new storage yards are proposed at Portsmouth, so no cultural resources would be affected. A new storage yard is proposed at the K-25 site; although the exact location of the yard is unknown, it would probably be located in an area already dedicated to similar use.

5.1.11 Environmental Justice

A review of the potential human health and safety impacts occurring under the no action alternative indicates that no disproportionately high and adverse effects to minority or low-income populations would be expected in the vicinity of the three current storage sites during normal operations. Although such populations reside within 50 miles (80 km) of the sites (see Appendix C), no disproportionate impacts would be expected. The results of accident analyses for the no action alternative also did not identify high and adverse impacts to the general public (i.e., the risk of accidents, consequence times probability, was less than one fatality for all accidents considered).

5.2 LONG-TERM STORAGE AS UF_6

Under the long-term storage as UF_6 alternative, the depleted UF_6 inventory was assumed to be stored in cylinders at a consolidated storage site through 2039. Three options were considered for the long-term storage of cylinders: storage in yards (similar to those currently used), storage in buildings, and storage in an underground mine (see Appendix G). To provide a conservative estimate of potential impacts, it was assumed that long-term storage would take place at a newly constructed, independent facility and that cylinders would be transported from the three current storage sites by either truck or rail.

The following is a summary of the activities analyzed under the long-term storage as UF_6 alternative:

- ***Continued Cylinder Storage (at Paducah, Portsmouth, and K-25).*** Depleted UF_6 cylinder storage was assumed to continue at each of the three current storage sites through 2028. The entire inventory would be stored at the sites through 2008, but the site inventory would decrease from 2009 through 2028 as cylinders were shipped off-site to a consolidated storage facility. The cylinder management activities that would occur at the sites were assumed to be similar to those for the no action alternative.

- ***Preparation of Cylinders for Shipment (at Paducah, Portsmouth, and K-25).*** In the future, a number of cylinders might not be suitable for transportation and might thus require some type of preparation prior to off-site shipment (see Section 4.2 and Appendix E). Two cylinder preparation options were considered for these cylinders: (1) a cylinder overcontainer option and (2) a cylinder transfer option. The cylinder overcontainer option would not require the construction of any new facilities; for the cylinder transfer option, it was assumed that a transfer facility would be constructed at each of the three sites. Preoperations for transfer facilities were assumed to occur between 1999 and 2008 (with actual construction requiring 4 years). Operations would occur between 2009 and 2028. Cylinder preparation impacts were evaluated for a range in the number of cylinders prepared at each site (as summarized in Section 4.2.2).

- ***Long-Term Storage (Representative Site).*** The three long-term storage options considered are storage in yards, storage in buildings, and storage in an underground mine (see Appendix G). Cylinders would be received at the storage facility from 2009 through 2028. Construction activities would also be ongoing from 2009 through 2028. Monitoring and maintenance were evaluated through 2039.

- ***Transportation (Representative Routes).*** All cylinders were assumed to be transported by either truck or rail from the Paducah, Portsmouth, and K-25 sites to an independent long-term storage site.

Under the long-term storage as UF_6 alternative, the cylinder management activities at the current storage sites were assumed to be similar to those that would occur under the no action alternative, including cylinder painting. However, because of impending cylinder movement or content transfer, cylinder yard improvement and cylinder painting might not occur at the same rate as they would under the no action alternative. Because the painting schedule that would be followed under the action alternatives (including long-term storage as UF_6) is not known, and to present reasonable upper bound estimates of impacts, no credit was taken for the effectiveness of cylinder yard improvements and painting in reducing cylinder corrosion rates. The number of hypothetical breached cylinders at the three current storage sites was estimated by assuming historical corrosion rates. Therefore, for analytical purposes, more cylinder breaches were assumed to occur under this alternative than under the base case for the no action alternative, even though the storage time at the current storage sites would be less.

5.2.1 Human Health and Safety

During implementation of the long-term storage as UF_6 alternative, potential impacts to human health and safety could result from facility operations during both routine conditions and accidents. Potential impacts are discussed in Sections 5.2.1.1 and 5.2.1.2.

5.2.1.1 Normal Facility Operations

5.2.1.1.1 Workers

At the three current storage sites, involved workers would be exposed to low-level radiation during routine cylinder monitoring and maintenance, cylinder relocation and painting, cylinder patching or repairing, and preparation of cylinders for shipment. Involved workers at a long-term storage facility would be exposed to radiation during the placement of cylinders into long-term storage. At all facilities, radiation exposure of workers would be maintained in accordance with ALARA practices.

Similar to the no action alternative, the radiation exposure of individual workers under the long-term storage as UF_6 alternative would be well within public health standards; average doses were estimated to be much less than the limit of 5,000 mrem/yr (10 CFR Part 835). The total radiation exposure of involved workers would be similar to, but slightly greater than, that under the no action alternative. The total exposure would be greater because of the additional cylinder handling required for preparation of cylinders for shipment and placement of cylinders into consolidated long-term storage. The estimated total number of potential radiation-induced LCFs among involved workers from 1999 through 2039 is summarized in Figure 5.1. (The totals include the radiation exposure during cleaning of empty cylinders that would be required if a cylinder transfer facility were used.) For all three storage options, about 1 additional LCF was estimated among the involved worker population, similar to the no action alternative. Impacts to noninvolved workers would be less than 1% of those to involved workers.

In addition to about 50 cylinder yard workers, 40 to 230 involved workers would be required under the long-term storage as UF_6 alternative (the exact number would depend on the cylinder preparation and storage options selected).

Impacts to involved and noninvolved workers from exposure to chemicals during normal operations would not be expected. The workplace would be monitored to ensure that airborne chemical concentrations were within applicable health standards that are protective of human health and safety. If planned work activities were likely to expose involved workers to chemicals, workers would be provided with appropriate protective equipment as necessary. The potential chemical exposure of noninvolved workers from airborne releases during normal operations was estimated to be below levels expected to cause adverse effects (the estimated hazard indices were less than 0.002 for noninvolved workers at all three sites and at a consolidated storage facility).

5.2.1.1.2 General Public

The potential impacts to members of the public during normal operations would be similar to those under the no action alternative — all exposures were estimated to be within applicable

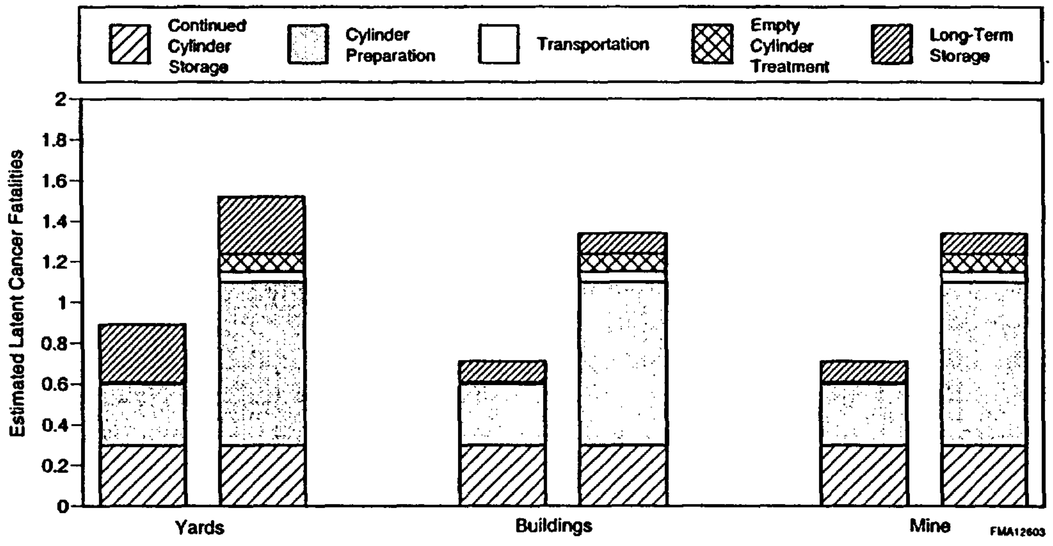

FIGURE 5.1 Total Estimated Number of LCFs among Involved Workers from Radiation Exposures during Normal Operations for the Long-Term Storage as UF_6 Alternative, 1999 through 2039 (Note: The two bars presented for each option represent the minimum and maximum impacts estimated.)

public health standards. No LCFs from radiation exposures and no adverse effects from chemical exposures were estimated to occur among members of the general public near the three current storage sites or near a consolidated long-term storage facility from depleted UF_6 management activities.

At the current storage sites, potential public exposures to radiation and chemicals were estimated to be slightly greater than under the no action alternative because, for the action alternatives, no credit was taken for reduced corrosion rates from cylinder painting and maintenance, resulting in an increased number of estimated cylinder breaches at the sites. However, the potential exposures of members of the general public were still estimated to be well within all applicable health standards and guidelines.

The total collective radiation dose to the general public around the three current storage sites from potential airborne emissions of uranium from breached cylinders was estimated to be about 1.1 person-rem over the period 1999 through 2028 (all cylinders were assumed to be removed by 2029). This level of exposure was estimated to result in zero LCFs among members of the general public. The maximum radiation dose to an individual near any of the sites was estimated to be less than 0.5 mrem/yr from airborne emissions, well within applicable health standards. Radiation doses to members of the general public are required by health regulations to be maintained below 10 mrem/yr from airborne sources (40 CFR Part 61) and below a total of 100 mrem/yr from all sources combined (DOE Order 5400.5). If an individual were to receive the maximum estimated dose every year (1999 through 2028), the total dose would be about 15 mrem, resulting in an chance of dying from a latent cancer of about 1 in 100,000. No noncancer health effects from exposure to airborne uranium and HF releases would be expected — the estimated hazard index for an individual was estimated to be less than 0.1 at all three sites. This means that the total exposure would be at least 10 times less than exposure levels that might cause adverse effects.

The results of the surface water and groundwater analyses indicate that the maximum estimated uranium concentrations would be less than the guideline level of 20 μg/L (EPA 1996) at all three sites. This is true even though a higher cylinder breach rate was assumed under the long-term storage as UF_6 alternative than under the no action alternative, because the cylinder inventory at the three sites would be steadily decreasing (see Sections 5.2.4.1 and 5.2.4.2). If a member of the general public near one of the sites were to use contaminated surface water or groundwater as a primary water source (at the maximum concentrations estimated to occur in the future), the annual radiation dose was estimated to be about 1 mrem/yr at all three sites. The corresponding chance of this individual dying from a radiation-induced latent cancer would be less than 1 in 1 million per year.

At a consolidated long-term storage site, cylinders would have undergone appropriate preparation at the current storage sites and would be inspected before being placed in storage. Once placed in storage, cylinders would be subjected to routine monitoring and maintenance activities similar to those occurring at the three current storage sites. If a breach occurred, storage in buildings or a mine would provide an additional level of containment when compared with yard storage. Consequently, impacts to members of the general public near a consolidated storage facility would be less than or equal to those discussed for the three current storage sites.

5.2.1.2 Facility Accidents

5.2.1.2.1 Physical Hazards (On-the-Job Injuries and Fatalities)

Accidents occur in all work environments. In 1994, about 5,000 work-related fatalities and 3.5 million work-related injuries were reported in the United States (National Safety Council 1995). Although all work activities would be conducted in as safe a manner as possible, there is a chance that workers could be accidentally killed or injured during the long-term storage as UF_6 alternative, unrelated to any radiation or chemical exposures.

The number of accidental worker injuries and fatalities that might occur from 1999 through 2039 was estimated on the basis of the number of workers required over this period and the historical accident fatality and injury rates in similar types of industries (see Appendix D, Section D.2). The estimated number of worker fatalities and injuries would be slightly greater than that under the no action alternative because of the additional construction and operational activities required for cylinder preparation and consolidated long-term storage facilities. It was estimated that a total of about 1 accidental fatality might occur over the 41-year period. Similarly, a total of between 240 and

900 accidental injuries was estimated. These rates would not be unique to the activities required for the alternative but would be typical of any industrial project of similar size and scope.

5.2.1.2.2 Accidents Involving Releases of Radiation or Chemicals

Under the long-term storage as UF_6 alternative, accidents that could release radiation and chemicals from cylinders are possible. A wide range of different types of accidents was evaluated at the current storage sites during continued cylinder storage and cylinder preparation activities and at a consolidated long-term storage facility. The accidents at these facilities that could result in a release of radiation or chemicals would all involve cylinders, either while in storage or during handling.

The consequences of the potential cylinder accidents that could occur at the current storage sites under the long-term storage as UF_6 alternative would be the same as those described under the no action alternative (see Section 5.1.1.2.2). In addition, the consequences of cylinder accidents at a consolidated storage facility would also be the same as those discussed for the no action alternative because the types of accidents possible are the same, and, for assessment purposes, the environmental conditions of the three current storage sites were assumed to be representative of the conditions at a long-term storage facility.

5.2.2 Transportation

The major materials assumed to be transported under the long-term storage as UF_6 alternative are summarized in Table 5.3. To provide a conservative estimate of potential transportation impacts, it was assumed that all depleted UF_6 cylinders (46,422) would be transported from the three current storage sites to a consolidated long-term storage facility. All shipments would be made in accordance with applicable DOE and DOT regulations and guidelines. Transport by rail would require about 11,600 railcar shipments (with four cylinders per railcar), and transport by truck would require about 46,422 truck shipments (with one cylinder per truck). The operation of a cylinder transfer facility at each of the current storage sites would also produce waste, including LLW and LLMW, that would require shipment to a disposal facility. A total of about 600 truck shipments of radioactive waste would be required over the duration of the program. Because of the relatively small number of shipments and the low concentration of radioactive and chemical contaminants expected, the potential impacts associated with waste shipments were estimated to be negligible compared to those associated with the transportation of UF_6 cylinders. All shipments were assumed to take place over a 20-year period.

The assessment of transportation impacts considered truck and rail shipment options and evaluated impacts from both incident-free transportation operations as well as accidents. Because the location of a long-term storage site is unknown, for assessment purposes it was assumed that all

TABLE 5.3 Summary of the Major Materials Assumed to Be Transported, Estimated Number of Shipments, and Estimated Number of Traffic Accident Fatalities under the Long-Term Storage as UF_6 Alternative, 1999 through 2039[a]

			Approximate Total Number of Shipments[b]		Estimated Traffic Accident Fatalities[c]	
Material	Origin	Destination	Truck	Rail	Truck	Rail
UF_6 cylinders	Current storage sites	Consolidated long-term storage site	46,422	11,600[d]	2	1
LLW/LLMW	Current storage sites	Treatment/disposal site	520 - 640	–	0	0

[a] All materials were assumed to be transported to provide a conservative estimate of transportation impacts. A hyphen (–) denotes mode not considered for that material. Colocation of facilities would reduce transportation requirements.

[b] Estimated number of shipments when either the truck or rail mode is assumed to be used.

[c] Number of estimated traffic accident fatalities when each shipment is assumed to travel 620 miles (1,000 km) and national average accident statistics are used. Estimates have been rounded to the nearest whole number.

[d] Number of railcars, each containing four cylinders.

shipments would travel a distance of 620 miles (1,000 km), primarily through rural areas but including some suburban and urban areas. The transportation assumptions and impacts for a range of shipment distances are discussed in detail in Appendix J. The transportation impacts could be reduced or eliminated by colocating facilities.

5.2.2.1 Normal Transportation (Incident-Free) Operations

During normal operations, radioactive materials and chemicals would be contained in their transport packages. Potential impacts would be possible from exposure to external radiation in the vicinity of cylinders and from exposure to vehicle engine exhaust emissions. Incident-free transportation operations were estimated to result in zero fatalities among workers and the general public, combined, for both truck and rail transportation. Members of the public living along truck and rail transportation routes were estimated to receive extremely small doses of radiation, much less than 0.1 mrem even if a single person were to be exposed to every shipment of radioactive material during the program.

5.2.2.2 Transportation Accidents

Transportation accidents could occur during the shipment of UF_6 cylinders. These accidents could potentially affect the health of workers (i.e., crew members) and members of the general public. Two types of accident impacts were estimated: (1) impacts from typical traffic accidents that could cause deaths from physical trauma, unrelated to the cargo being shipped, and (2) accidents that would involve the release of radioactive material or chemicals from a shipment.

5.2.2.2.1 Traffic Accidents with No Release

Shipments of cylinders and waste could be involved in truck or rail traffic accidents, with a chance that fatalities could result. To predict the number of traffic fatalities that might result from future shipments, historical traffic accident statistics were used. The estimated number of traffic fatalities depends on the total number of shipments, the shipment distance, the shipment mode (truck or rail), and the historical accident fatality rates.

The number of traffic fatalities estimated assuming the shipment of all 46,422 cylinders by truck or rail over a 20-year period are presented in Table 5.3 (for purposes of comparison, shipments were assumed to travel 620 miles [1,000 km]). If truck shipments were used, it was estimated that about 2 traffic fatalities could result. If rail shipments were used, it was estimated that about 1 traffic fatality could result. Rail transport results in a lower number of estimated traffic fatalities, primarily because railcars have a larger shipment capacity than trucks, resulting in fewer shipments. The estimated number of fatalities would be reduced if the number of shipments and shipment distances were reduced.

5.2.2.2.2 Traffic Accidents Involving Releases of Radiation or Chemicals

Traffic accidents that could cause a release of UF_6 from cylinders are possible. The amount released would depend on the severity of the accident and the number of cylinders involved. Following a release, the UF_6 would combine with moisture in the air, forming gaseous HF and UO_2F_2. The depleted uranium and HF would be dispersed downwind, potentially exposing members of the general public to radiation and chemical effects. The consequences of such a release would depend on the location of the accident and the weather conditions at the time. Potential consequences would be greatest in urban areas because more people could be exposed. Accidents that occurred when the weather was very stable (typical of nighttime conditions) would have greater potential consequences than accidents that occurred when the weather was unstable (i.e., turbulent, typical of daytime conditions) because the stability of the weather would determine how quickly the released material was dispersed and diluted to lower concentrations as it moved downwind.

Severe rail accidents could have higher consequences than truck accidents because each railcar would carry four cylinders, compared to one cylinder per truck. The accident estimated to have the largest potential consequences would be a severe rail accident involving four cylinders. The consequences of such an accident were estimated on the basis of the assumption that the accident occurred in an urban area under stable weather conditions (such as at nighttime). In such a case, it was estimated that approximately 4 persons might experience irreversible adverse effects (such as lung or kidney damage) from exposure to HF and uranium. The number of fatalities expected following an HF or uranium chemical exposure is expected to be somewhat less than 1% of the potential irreversible adverse effects. Thus, no fatalities would be expected (1% of 4). Over the long term, radiation effects are possible from exposure to the uranium released. In a highly populated urban area, it was estimated that about 3 million people could be exposed to small amounts of uranium as it was dispersed by the wind. Among those exposed, it was estimated that approximately 60 LCFs could occur in the urban population in addition to those occurring from all other causes. In a population of 3 million people, approximately 700,000 would be expected to die of cancer from all causes.

The occurrence of a severe rail accident breaching four cylinders in an urban area under stable weather conditions would be expected to be rare. The total probability of an urban rail accident involving a release (not taking into account the frequency of weather conditions) was estimated to be about 1 chance in 10,000 (8×10^{-5}) for shipping all the cylinders by rail over 20 years (the actual probability would depend on the route selected). The total accident risk from cylinder shipments was calculated by using the probability and consequences of the range of possible accident severities. The results indicate that zero fatalities from accidental radioactive and chemical releases would be expected over the 20-year shipment period (see Appendix J, Table J.6).

The consequences of cylinder accidents occurring in rural environments, during unstable weather conditions (typical of daytime) or involving a truck shipment, were also assessed. The consequences of all other accident conditions were estimated to be considerably less than those described above for the severe urban rail accident. These considerations are discussed further in Appendix J.

Although accidents involving shipments of LLW and LLMW could occur, the consequences of even the most severe accidents involving these materials would not be expected to cause any LCFs from radiation exposures or any irreversible adverse effects from exposure to chemicals if a release occurred.

5.2.3 Air Quality

The analysis of potential impacts to air quality for the long-term storage as UF_6 alternative considered the potential for air pollutant emissions from continued cylinder storage activities through 2028, cylinder preparation activities, and long-term storage activities at a consolidated site. The analysis of continued cylinder storage at the current sites considered construction of new yards, maintenance and operations, and HF emissions from breached cylinders, as described in Section 5.1.3. Estimated concentrations of criteria pollutants for continued storage activities were all within applicable standards and guidelines. However, because potential PM_{10} concentrations during construction activities were estimated to be close to the standards, procedures to reduce these emissions might have to be implemented during actual construction activities. In addition, the maximum 24-hour average HF concentrations at the K-25 site could be as high as 92% of the State of Tennessee standard for HF. This HF value is greater than that estimated under the no action alternative because, for the action alternatives, no credit was taken for reduced corrosion rates from cylinder painting and maintenance, thus resulting in an increased number of estimated cylinder breaches at the sites. Actual HF concentrations would be lower because improved cylinder storage conditions and painting activities are expected to reduce corrosion rates.

For construction activities that could occur as a part of cylinder preparation (i.e., if a transfer facility was constructed), estimated PM_{10} concentrations would also be within standards (62, 36, and 87% of the standards at Paducah, Portsmouth, and K-25, respectively). Procedures to reduce these emissions might have to be implemented during actual construction of a cylinder transfer facility. All other activities occurring as a part of cylinder preparation and consolidated storage facility construction and operations were estimated to result in criteria pollutant concentrations of less than 20% of standards. The analysis indicated that potential HF emissions from cylinder preparation and consolidated storage activities would be less than those estimated for continued cylinder storage at the current sites and thus would be within applicable standards.

5.2.4 Water and Soil

Water use from continued cylinder storage construction activities would range from 0.8 to 2 million gal. For operations, the water use would range from 32,000 to 160,000 gal/yr. The amounts of wastewater generated would be very small.

Construction activities for cylinder preparation would require from 6.5 to 10 million gal/yr (about 26 to 40 million gal total) of water if a transfer facility was constructed; operation of a transfer facility would require between 6 and 9 million gal/yr of water. Wastewater generated would be between 3 and 7 million gal/yr.

For consolidated storage in yards, buildings, or a mine, water use during construction would be between 0.5 and 6.4 million gal/yr; maximum water use during operations would be about 1.2 million gal/yr. Wastewater generation would be about 1.1 million gal/yr for all storage options.

5.2.4.1 Surface Water

Under the long-term storage as UF_6 alternative, potential impacts on surface water at the current storage sites could occur during continued storage of the cylinders through 2028. As for the no action alternative (Section 5.1.4), the only area with potentially important impacts was determined to be water quality. Impacts to the nearest receiving water at each site (Little Bayou Creek at

Paducah, Little Beaver Creek at Portsmouth, and Poplar Creek at K-25) were estimated for uranium released from hypothetical cylinder breaches occurring through 2028. The estimated maximum concentrations of uranium in receiving waters were estimated to be less than 2 µg/L for all three sites. These concentrations are considerably below the 20-µg/L guideline used for comparison. The water would then mix with water in the Ohio River, Scioto River, or Clinch River, resulting in even lower uranium concentrations.

Surface water impacts with respect to runoff and floodplain encroachment from cylinder preparation activities would be none to negligible (none for the cylinder overcontainer option; changes of less than 0.0006% in average river flows for the cylinder transfer facility option). Concentrations of uranium released in wastewater would be very low and would result in concentrations much lower than 20 µg/L in the surface waters to which wastewaters would be released.

For consolidated storage of UF_6 cylinders, the changes in average river flows for the representative sites would be less than 0.0001%, so impacts to runoff and floodplain encroachment, although dependent on the actual site location, would probably be negligible. Concentrations of uranium released in wastewater would be very low and would result in concentrations much lower than 20 µg/L in the surface waters to which wastewaters would be released.

5.2.4.2 Groundwater

Potential impacts on groundwater quality at the current storage sites from uranium releases due to hypothetical breached cylinders were assessed for continued storage through 2028; the maximum concentrations of uranium in groundwater beneath the sites were estimated to be 20, 4, and 9 µg/L for the Paducah, Portsmouth, and K-25 sites, respectively. These estimated concentrations would occur some time after the year 2070 and are based on the assumption of a rapid rate of uranium migration through the soil to the groundwater. Lower concentrations would occur if uranium migration through the soil was slower. Although the estimated groundwater concentration for Paducah is equal to the 20 µg/L guideline used for comparison, this is the maximum concentration estimated to occur and, because of conservatism in the calculations (e.g., the effects of cylinder painting in limiting corrosion were not considered), it is unlikely that groundwater concentrations would actually reach 20 µg/L at the Paducah site. Potential groundwater impacts would be mitigated by collecting and treating runoff from the cylinder yards and by identifying and repairing breached cylinders as soon as possible. (See Section 5.1.4 for a discussion of groundwater use in the vicinity of the three current storage sites.)

For cylinder preparation activities, impacts on depth to groundwater and flow direction would be none or negligible, depending on whether facility construction was required and whether groundwater or surface water was used during construction and operations. Good engineering and construction practices would be followed to minimize the potential for adverse impacts during construction. No releases to groundwater would occur during normal operations.

At a consolidated storage facility, the potential impacts to groundwater would depend on the actual facility location and on whether yards, buildings, or mines were used. Good engineering and construction practices would be followed to minimize the potential for adverse impacts during construction. If yards were used for storage, impacts would be less than those described for continued storage under the no action alternative because the cylinders in need of improvement would all have been subject to cylinder preparation (e.g., transferred to new cylinders) prior to consolidated storage. (Under the no action alternative, concentrations of uranium in groundwater from continued cylinder storage were estimated to be less than 5 μg/L.) No releases to groundwater were assumed to occur during normal operations under the building or mine storage options because rainwater would not come into contact with cylinders in buildings and mine storage was assumed to be in a dry environment.

5.2.4.3 Soil

Under the storage as UF_6 alternative, potential impacts to soil at the three current storage sites could occur during continued storage of the cylinders through 2028. As for the no action alternative (Section 5.1.4), impacts to soil receiving contaminated runoff from the cylinder storage yards were estimated by assuming the source to be uranium released from hypothetical breached cylinders. The estimated maximum soil concentration was 7 μg/g for the three current storage sites. This maximum soil concentration was higher than that calculated for the no action alternative because of conservatism in the calculations (e.g., the effects of cylinder painting in limiting corrosion were not considered). This concentration is well within the 230-μg/g guideline used for comparison.

For cylinder preparation activities, if a transfer facility were constructed at each of the current storage sites, from 0.4 to 0.7% of available land would be required. Even if this construction occurred on previously undisturbed land, which is unlikely, the impacts with respect to permeability and erosion potential would be negligible, and remaining unpaved areas would be returned to their former condition with regrading and reseeding.

At a consolidated storage facility, soil impacts would depend on whether yards, buildings, or a mine were the selected option and on the facility location. The impacts, which would tend to be temporary, would generally result from material excavated during construction that would be left on-site. The largest potential impacts on soil would occur for storage in a mine. Construction of a mine for storage could require excavating about 1.8 million yd^3 (1.4 million m^3) of consolidated material. In the short term, this amount of material would cause changes in site topography. In the long term, contouring and reseeding would return soil conditions back to their former state, and the impacts would be minor. If a previously existing mine were used for storage, excavation requirements could be significantly reduced and potential impacts to soils would be much less. Potential impacts to soil for yard and building storage facilities would be much less than storage in a mine.

5.2.5 Socioeconomics

The potential socioeconomic impacts of construction and operational activities would be low for continued storage at the current sites through 2028. Construction activities at the Paducah and K-25 sites would create short-term employment (30 direct jobs, 110 total jobs in the peak construction year); operational activities occurring at the three sites would create 120 direct jobs and 260 total jobs per year. Direct and total income from construction in the peak year would be $1.4 million and $3.5 million, respectively. During operations, direct and total income would be $6 million/yr and $7.9 million/yr, respectively. Differences from the no action alternative would be due to different painting schedules and different assumptions concerning the number of breached cylinders. Employment and income created would represent a change of less than 0.01% of projected growth in these indicators of overall regional activity. The in-migration expected into each region with each activity would have only a minor impact on regional population growth rates and would require less than 2% of vacant housing stock at each of the three sites. No significant impacts on local public finances would be expected.

The potential socioeconomic impacts of construction and operational activities for cylinder preparation at the current sites would also be minor. If the largest number of cylinders required overcontainers or transfer at the three sites, from 0 to 580 direct jobs and 0 to 960 total jobs would be created during preoperations (0 corresponds to use of overcontainers; the high end of the ranges corresponds to construction of transfer facilities at each site). Operational activities for cylinder preparation occurring at the three sites would create from 300 to 490 direct jobs and from 610 to 1,230 total jobs. Direct and total income from preoperations in the peak year would range from 0 to $26 million and 0 to $33 million, respectively. During operations, direct and total income would range from $19 to $25 million/yr and $22 to $37 million/yr, respectively. Employment and income created would represent a change of less than 0.04% of projected growth in these indicators of overall regional activity for any of the three sites. The in-migration expected into each region would have only a small impact on regional population growth rates and would generally require less than 5% of vacant housing stock at each of the three sites. (During the peak year of construction at the Paducah site, 10% of rental housing units could be required.) No significant impacts on local public finances would be expected.

The potential socioeconomic impacts of construction and operational activities at a consolidated storage facility would depend on the facility location and whether yards, buildings, or a mine were selected. Construction activities would create employment (100 to 500 direct jobs in the peak construction year); operational activities would create 50 to 60 direct jobs per year. Direct income from construction in the peak year would be from $5 to $29 million. During operations, direct income would be about $3 million/yr. For long-term storage, construction and operations would be occurring concurrently over the 20-year emplacement period.

For the representative settings used for analysis, the employment and income created would represent a change of less than 0.02% of projected growth in these indicators of overall regional activity (see Appendix G, Section G.3.5). The in-migration expected into the region of a consolidated storage facility would have only a small impact on regional population growth rates. Negligible impacts on local public finances would be expected. The impacts of mine storage were calculated for a generic site; therefore, no estimates of indirect impacts on employment and income were made for mine options.

5.2.6 Ecology

The long-term storage of UF_6 cylinders at a consolidated facility could potentially impact ecological resources, primarily from construction. A very limited amount of construction activity is planned for continued storage at the current storage sites, and that planned would all occur in previously developed areas. Thus, impacts to wetlands and state and federally protected species due to facility construction would be negligible. Construction of a transfer facility at any of the three current storage sites would require at most up to 21 acres (11 ha), which would be expected to result in only moderate ecological impacts because of the large amounts of previously disturbed land at these sites. The construction of a long-term storage facility would disturb between 96 and 144 acres (38 to 58 ha), depending on the type of storage facility. Existing vegetation at the site would be destroyed during land-clearing activities. In addition, wildlife would be disturbed by land clearing, noise, and human presence. The extent of the impacts on ecological resources would depend on the location of the facility; however, some permanent loss of habitat could result. Impacts to wetlands and state and federally protected species due to facility construction would also depend on the facility location. Avoidance of wetland areas would be included during facility planning, and site-specific surveys for protected species would be conducted prior to finalization of facility siting plans.

Impacts to ecological resources from facility operations at the current storage sites or a long-term storage site would be negligible to low. The concentrations of radioactive and chemical contaminants in air and water emissions would be considerably below levels considered harmful to vegetation and wildlife.

Facility and transportation accidents, as discussed in Sections 5.2.1 and 5.2.2, could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on a number of factors, such as accident location, season, and meteorological conditions.

5.2.7 Waste Management

Under the long-term storage as UF_6 alternative, construction and operations for continued storage at the three current storage sites through 2028 would generate relatively small amounts of LLW and LLMW. The volume of LLW generated by continued storage activities would represent less than 1% of the annual generation at each of the three sites, and the total would be less than 1% of projected annual DOE LLW treatment volumes, indicating negligible impacts associated with LLW disposal. The maximum annual amount of LLMW generation from stripping/painting operations at the Paducah site would generate about 20% of the site's total annual LLMW load, constituting a potential moderate impact on LLMW management. (The maximum annual LLMW generation amount is not decreased in comparison with the no action alternative, because most of the cylinder painting would occur in the early years of maintenance under both alternatives.) LLMW generation for the Portsmouth and K-25 sites would be less than 1% of site LLMW generation, resulting in negligible waste management impacts for these sites. The total volume of LLMW generated at all three sites would also be less than 1% of the total DOE LLMW load, so that overall waste management impacts from continued storage through 2028 would be negligible to small.

The waste management impacts from cylinder preparation activities would be greater if the cylinder transfer option were implemented than if the cylinder overcontainer option were implemented (see Section E.3.7). The cylinder transfer option would require construction and operation of both cylinder transfer and cylinder treatment facilities at each site. The waste management impacts from cylinder transfer facilities would be minimal, representing less than 7% of the various types of waste loads at any of the three sites.

The waste management impacts from operating a cylinder treatment facility capable of treating the entire cylinder inventory are presented in Section F.3.7.4. Construction of this cylinder treatment facility would generate about 18 m^3 of hazardous waste; its operation would generate about 48 m^3/yr of LLW, 0.2 m^3/yr of LLMW, and 2 m^3/yr of hazardous waste. These volumes would represent negligible impacts to the waste management system. However, they exclude the crushed cylinders, which would represent a volume of about 6,200 m^3/yr. It was assumed that treated crushed cylinders would become part of the DOE scrap metal inventory. If a decision to dispose of the crushed cylinders was made, the treated cylinders would be disposed of as LLW, representing a 3% addition to the projected DOE complexwide LLW disposal volume. Under the cylinder transfer option, an unknown number of empty cylinders requiring treatment would be generated. The number of empty cylinders would range from about 9,600 to 28,351 at the Paducah site, 2,600 to 13,388 at the Portsmouth site, and 2,342 to 4,683 at the K-25 site. The impacts from disposal of the empty crushed cylinders would be proportional to the percentage of the inventory requiring cylinder transfer.

The operation and construction of a consolidated long-term storage facility would generate LLW and LLMW. The generation of LLW would result from the repair or repackaging of failed cylinders. The long-term storage of UF_6 would generate a total of approximately 2,150 m^3 of LLW and 560 m^3 of LLMW for storage in yards, and about 60 m^3 of LLW for storage in either buildings or a mine. Compared with national and regional waste management capabilities (see Appendix C, Section C.10), the generation of waste under the long-term storage as UF_6 alternative would have a negligible to small impact.

5.2.8 Resource Requirements

Construction and operation of facilities under the long-term storage as UF_6 alternative would consume electricity, fuel, concrete, steel and other metals, and miscellaneous chemicals that are generally irretrievable resources. The total quantities of commonly used materials are not expected to be significant and would not affect local, regional, or national availability of these materials. Very small amounts of strategic or critical materials are projected to be consumed during construction or operation of the facilities. In general, facility operational requirements are not resource intensive, and the resources required are not considered rare or unique. However, for storage in a mine, large quantities of electrical energy would be required during construction (about 840 MW-yr) because the majority of the construction equipment required to build the underground portion would be powered by electricity. The impact of this high electrical requirement on local energy resource use would be dependent on the location of the facility and the existing infrastructure. If a previously existing mine were used for storage, excavation and construction requirements would probably be reduced, depending on the characteristics and condition of the mine, and the electrical requirements would be subsequently reduced.

5.2.9 Land Use

The long-term storage as UF_6 alternative would result in negligible impacts to land use at the current cylinder storage sites. The maximum amount of additional land required for continued cylinder storage at any of the current storage sites would be less than 7 acres (2.8 ha), representing much less than 1% of the land available for development at the sites. Construction of a cylinder transfer facility at the current storage sites could require up to 21 acres (9 ha), but such an areal requirement would result in negligible land-use impacts at these sites.

Impacts on land use for consolidated long-term storage would depend on the location of the facility. The construction and operation of a long-term storage facility would require between 96 and 144 acres (38 to 58 ha), constituting a potentially moderate land use impact. For storage in a mine, on-site topographical modifications associated with the disposition of excavated material could potentially affect future on-site land use. Impacts to land use outside the boundaries of facilities would be negligible and limited to temporary traffic impacts associated with construction.

5.2.10 Cultural Resources

Impacts to cultural resources under the long-term storage as UF_6 alternative would be unlikely at the Paducah or Portsmouth sites. The existing and proposed storage yards at Paducah are located in previously disturbed areas unlikely to contain cultural properties or resources listed on or eligible for the *National Register of Historic Places*. No new storage yards are proposed at Portsmouth, so no cultural resources would be affected. A new storage yard is proposed at the K-25 site; although the exact location of the yard is unknown, it would probably be located in an area already dedicated to similar use. See Chapter 3 for a discussion of cultural resources existing at the three storage sites.

No impacts to cultural resources would be expected at the three current storage sites as a result of the cylinder overcontainer option because construction of a new facility would not be required. Impacts could result from the cylinder transfer option during construction of the transfer facilities. Specific impacts cannot be determined at this time and would depend on the future location of the facilities and whether listed or eligible cultural resources existed on or near that location. Operation of the transfer facility would not affect cultural resources. The impacts to cultural resources from the construction and operation of a consolidated long-term storage facility cannot be determined until the location of the facility is selected. However, impacts to cultural resources would be evaluated in Phase II studies and avoided if necessary and appropriate.

5.2.11 Environmental Justice

A review of the potential human health and safety impacts occurring for continued storage and cylinder preparation activities indicates that no disproportionately high and adverse effects to minority and low-income populations would be expected in the vicinity of the three current storage sites during normal operations. Although such populations reside within 50 miles (80 km) of the sites (see Appendix C), no disproportionate impacts would be expected. The results of accident analyses for continued cylinder storage and cylinder preparation activities also did not identify high and adverse impacts to the general public (i.e., the risk of accidents, consequence times probability, was less than 1). Moreover, because transportation routes are not currently known, and because it is impossible to reliably predict who would be involved in transportation accidents, there is no reason to believe that the impacts of transportation accidents would affect minority or low-income populations disproportionately.

5.3 LONG-TERM STORAGE AS URANIUM OXIDE

Under the long-term storage as uranium oxide alternative, depleted UF_6 was assumed to be chemically converted to an oxide at a conversion facility and the oxide placed in long-term storage. Conversion of depleted UF_6 to an oxide was assumed to take place at a newly constructed, stand-alone facility dedicated to the conversion process. Potential impacts were evaluated for conversion to and storage as both U_3O_8 and UO_2 (see Appendices F and G). For each, several long-term storage options were considered, including storage in buildings, belowground vaults, and an underground mine. To provide a conservative estimate of potential transportation and construction impacts, the conversion and long-term storage facilities were assumed to be located at sites other than the three current cylinder storage sites. Thus, transportation of cylinders from the three current storage sites to a conversion facility and transportation of uranium oxide from the conversion facility to a long-term storage facility were assumed.

The following is a summary of the activities analyzed under the long-term storage as uranium oxide alternative:

- ***Continued Cylinder Storage (at Paducah, Portsmouth, and K-25).*** Depleted UF_6 cylinder storage was assumed to continue at each of the three current storage sites through 2028. The entire inventory would be stored at the sites through 2008, but the site inventory would decrease from 2009 through 2028 as cylinders were shipped off-site to a conversion facility. The cylinder management activities that would occur at the sites were assumed to be similar to those under the no action alternative.

- ***Preparation of Cylinders for Shipment (at Paducah, Portsmouth, and K-25).*** Two cylinder preparation options for cylinders not meeting transportation requirements were considered: (1) a cylinder overcontainer option and (2) a cylinder transfer option (see Appendix E). The cylinder overcontainer option would not require the construction of any new facilities; for the cylinder transfer option, it was assumed that a transfer facility would be constructed at each of the three current storage sites.

- ***Conversion (Representative Site).*** Conversion was assumed to occur from 2009 through 2028 at a newly constructed, stand-alone conversion facility. Preoperations for conversion facilities were assumed to occur between 1999 and 2008 (with actual construction requiring 4 years).[1] As described in Appendix F, two representative conversion technologies were assessed for conversion to U_3O_8, and three for conversion to UO_2. The principal product of conversion would be either anhydrous HF, which would be shipped to a user facility, or CaF_2, which could be shipped for use or disposal.

- ***Transportation (Representative Routes).*** All UF_6 cylinders were assumed to be transported by either truck or rail from the Paducah, Portsmouth, and K-25 sites to a conversion site. Following conversion, the U_3O_8 or UO_2 produced was assumed to be transported in drums by truck or rail to a long-term storage facility. In addition, HF and CaF_2 were assumed to require transportation to either a user or disposal facility.

- ***Long-Term Storage (Representative Site).*** Three options were considered for the storage of oxide, including storage in buildings, vaults, and a mine (see Appendix G). Drums of oxide were assumed to be received at the storage facility from 2009 through 2028. Construction of the facility would continue over a 20-year period while drums were being received. Following the

[1] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

placement of the last container of oxide at the storage facility, monitoring and maintenance would occur from 2029 through 2039.

As described for the long-term storage as UF_6 alternative, cylinder management activities at the current storage sites for the long-term storage as oxide alternative were assumed to be similar to those that would occur under the no action alternative, including cylinder painting. As described for the long-term storage as UF_6 alternative, to provide a conservative estimate of impacts, no credit was taken for the effectiveness of cylinder yard improvements, cylinder maintenance, and painting in reducing cylinder corrosion rates. The number of hypothetical breached cylinders at the three current storage sites was estimated by assuming historical corrosion rates. Therefore, it was assumed that more cylinder breaches would occur under the long-term storage as oxide alternative than under the no action alternative, even though the cylinder storage time at the current storage sites would be shorter.

In terms of potential environmental impacts, the most important difference between the long-term storage as oxide alternative and the no action alternative is the requirement of a conversion facility. Conversion of UF_6 to uranium oxide would require process chemicals, most notably ammonia. Conversion could also produce large quantities of anhydrous HF. If accidentally released, both of these chemicals could cause serious adverse effects. Accidental releases of these chemicals could potentially occur at a conversion facility or during transportation. If the HF produced by conversion were neutralized to form CaF_2, shipments of anhydrous HF could be avoided. The potential environmental consequences of all activities under the storage as uranium oxide alternative, as outlined above, are provided in Sections 5.3.1 through 5.3.11.

The DOE plan for the management of the depleted UF_6 inventory that was in place during most of the preparation of this PEIS (described in Sewell 1992) is summarized in Section 1.1. The activities described under the former plan are very similar to those considered under the long-term storage as oxide alternative. The primary difference between the former plan and the long-term storage as oxide alternative is one of timing. Under the former plan, conversion of UF_6 to uranium oxide was anticipated to begin in 2020 and to continue for 20 years, through 2039. Under the long-term storage as oxide alternative, conversion is assumed to begin in 2009 and also to continue for 20 years, through 2028 (storage of the oxide was evaluated from 2029 through 2039). Therefore, under the former plan, cylinders would remain at the sites for about 10 years longer than is assumed under the long-term storage as oxide alternative. However, the environmental impacts for the long-term storage as oxide alternative are considered to be representative of those that would occur under the former management plan.

5.3.1 Human Health and Safety

During implementation of the long-term storage as oxide alternative, potential impacts to human health and safety could result from facility operations during both routine conditions and accidents. The principal facilities involved include the current storage sites, a conversion facility, and a consolidated long-term storage facility. These impacts are discussed in Sections 5.3.1.1 and 5.3.1.2.

5.3.1.1 Normal Facility Operations

5.3.1.1.1 Workers

The total radiation exposure of involved workers under the long-term storage as oxide alternative would be greater than under the no action alternative because of the additional activities required for preparation of cylinders for shipment, conversion operations, and long-term storage operations. However, the exposures would still be well within all applicable health standards.

At the three current storage sites, involved workers would be exposed to low-level radiation during routine cylinder monitoring and maintenance, cylinder relocation and painting, cylinder patching or repairing, and preparation of cylinders for shipment. Involved workers at a conversion facility would be exposed to radiation while handling incoming cylinders, during conversion operations, and while handling uranium oxide. At a long-term storage facility, involved workers would be exposed to radiation during the placement of drums of uranium oxide into long-term storage. At all facilities, radiation exposure of workers would be maintained in accordance with ALARA practices.

The estimated number of potential radiation-induced LCFs among involved workers from 1999 through 2039 is summarized in Figure 5.2. About 1 to 2 additional LCFs were estimated among the involved worker population, compared with 1 for the no action alternative. The impacts to involved workers would be similar for the storage of U_3O_8 and UO_2. In addition, the impacts would be essentially the same for storage in buildings, vaults, or a mine because all three options would involve handling the same amount of radioactive material and would require the same general types of activities. Radiological impacts to noninvolved workers were estimated to be negligible compared to those for involved workers (i.e., less than 1% of the involved worker impacts).

Impacts to involved and noninvolved workers from exposure to chemicals during normal operations are not expected. The workplace would be monitored to ensure that airborne chemical concentrations are within applicable health standards that are protective of human health and safety. If planned work activities were likely to expose involved workers to chemicals, workers would be provided with appropriate protective equipment, as necessary. The potential chemical exposure of noninvolved workers from any airborne releases during normal operations was estimated to be below levels expected to cause adverse effects (the estimated hazard indices were less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, and a consolidated storage facility).

5.3.1.1.2 General Public

The potential impacts to members of the general public during normal operations would be similar to those under the no action alternative — all exposures were estimated to be within

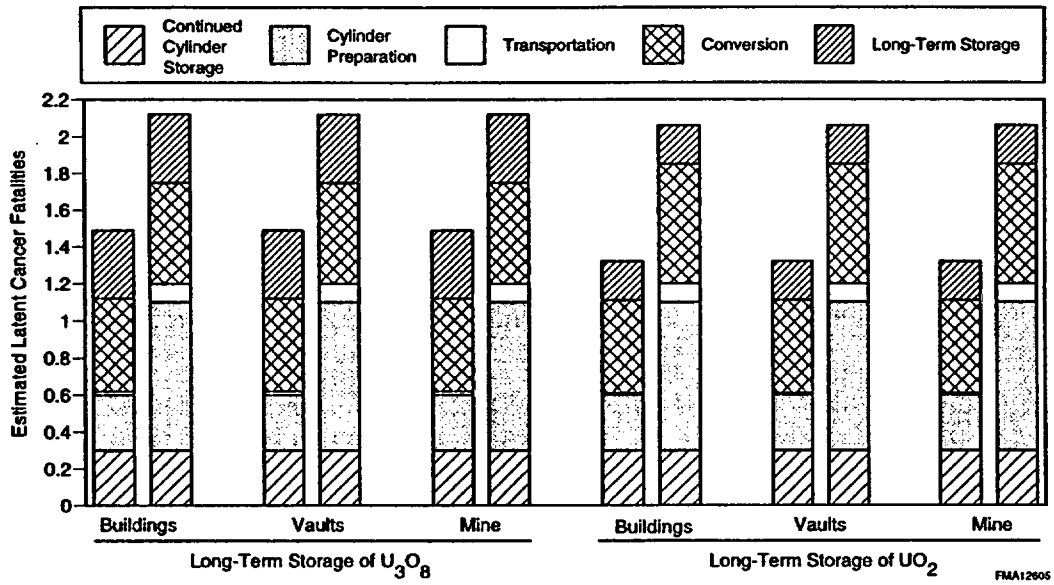

FIGURE 5.2 Total Estimated Number of LCFs among Involved Workers from Radiation Exposures during Normal Operations for the Long-Term Storage as Oxide Alternative, 1999 through 2039 (Note: The two bars presented for each option represent the minimum and maximum impacts estimated.)

applicable public health standards. No LCFs from radiation exposures and no adverse effects from chemical exposures were estimated to occur among members of the general public near the three current storage sites, near a conversion facility, or near a consolidated long-term storage facility from depleted UF_6 management activities.

At the current storage sites, potential public exposures to radiation and chemicals released from the sites would be exactly the same as described in Section 5.2.1.1.2 for the long-term storage as UF_6 alternative.

At a conversion facility, members of the general public could potentially be exposed to small amounts of uranium and HF released to the air during normal operations. The total collective radiation dose to the general public from airborne emissions was estimated to range from about 1.0 to 10 person-rem over the operational period of the conversion facility (2009 through 2028). This range takes into account the different conversion options and environmental settings considered (see Appendix F). This level of exposure was estimated to most likely result in zero LCFs among members of the general public. The maximum radiation dose to an individual near a conversion site was estimated to be less than about 0.03 mrem/yr from airborne emissions, well within applicable health standards (40 CFR Part 61; DOE Order 5400.5). If an individual were to receive the maximum estimated dose every year the conversion facility operated (2009 through 2028), the total dose would be about 1 mrem, with a resulting chance of dying from a radiation-induced latent cancer of less than 1 in 1 million. No noncancer health effects from exposure to airborne uranium and HF be expected — the hazard index for an individual near a conversion facility was estimated to be less than 0.0002.

At a consolidated long-term storage site, drums of uranium oxide would be stored within buildings, vaults, or a mine. The engineering analysis report indicates that emissions of uranium or chemicals from the storage facilities during normal operations would be negligible (LLNL 1997a). Drums would be routinely inspected and repaired, if necessary, and the storage facilities would include high-efficiency air filters. Therefore, no adverse health impacts to the general public in the vicinity of the storage site would be expected during normal operations.

5.3.1.2 Facility Accidents

5.3.1.2.1 Physical Hazards (On-the-Job Injuries and Fatalities)

Accidents occur in all work environments. In 1994, about 5,000 work-related fatalities and 3.5 million work-related injuries were reported in the United States (National Safety Council 1995). Although all work activities would be conducted in as safe a manner as possible, there is a chance that workers could be killed or injured during the long-term storage as oxide alternative as a result of accidents unrelated to any radiation or chemical exposures.

The accidental worker injuries and fatalities that might occur from 1999 through 2039 were estimated on the basis of the number of workers required over this period and the historical accident fatality and injury rates in similar types of industries. The estimated number of worker fatalities and injuries would be greater than it would be under the no action alternative because of the additional construction and operational activities required for cylinder preparation, conversion, and consolidated long-term storage facilities. The number of fatalities and injuries would depend on the specific cylinder preparation, conversion, and long-term storage options. Considering all options, a range of 1 to 2 accidental worker fatalities was estimated over the 41-year period.

The number of estimated worker injuries (injuries resulting in lost workdays) is shown in Figure 5.3. Considering all storage facility options, the estimated total number of injuries would range from about 700 to 1,600 over the 41-year period. At the current storage sites, the maximum total number of injuries was estimated to be about 700, assuming that a cylinder transfer facility would be constructed and operated at each site. If cylinder overcontainers were used as the cylinder preparation option, a maximum of about 150 worker injuries was estimated at the three sites combined. Approximately 460 to 660 worker injuries were estimated to occur at a conversion facility (including treatment of empty cylinders), and approximately 100 to 200 worker injuries were estimated to occur at a long-term storage facility. The total number of injuries for storage as U_3O_8 or UO_2 would be similar. These rates would not be unique to the activities required for the alternative but would be typical of any industrial project of similar size and scope.

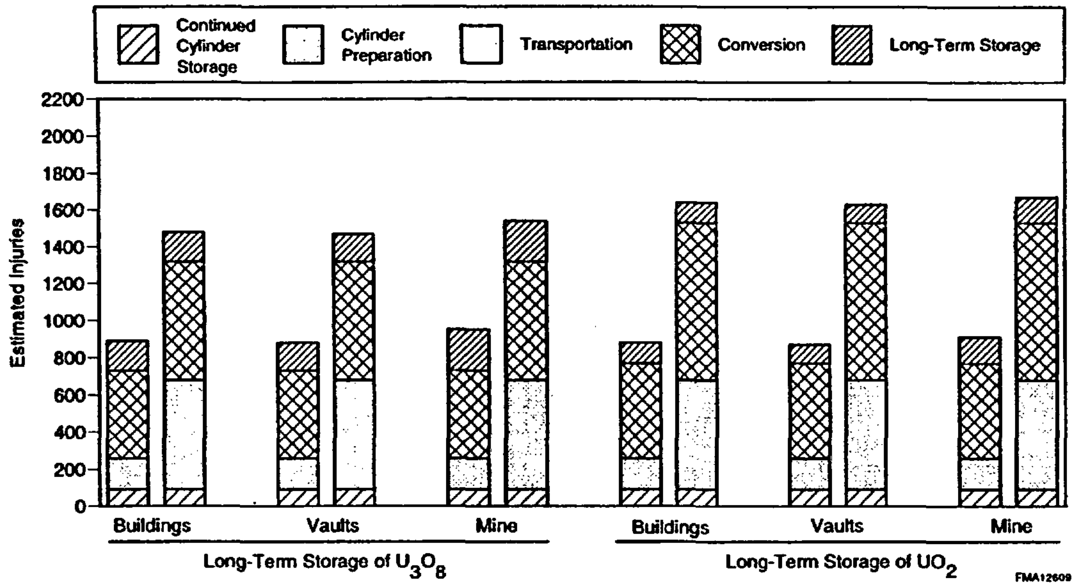

FIGURE 5.3 Total Estimated Number of On-the-Job Injuries (defined as injuries resulting in lost workdays) among All Workers from Construction and Operation of Facilities for the Long-Term Storage as Oxide Alternative, 1999 through 2039 (The two bars for each option represent the minimum and maximum impacts estimated.)

5.3.1.2.2 Accidents Involving Releases of Radiation or Chemicals

Under the long-term storage as oxide alternative, accidents potentially releasing radiation and chemicals could occur at the three current storage sites (during continued cylinder storage through 2028), at a conversion site, and at a long-term storage site. At each site, a range of accidents was evaluated, from those considered reasonably likely to occur (once or more in 100 years on average) to those that would be extremely rare (expected to occur less than once in 1 million years on average). The accidents considered are described in Appendix D, Section D.2.2, for continued cylinder storage; Appendix F, Section F.3.2, for conversion; and Appendix G, Section G.3.2, for long-term storage. The consequences of accidents were estimated for both the noninvolved workers at the sites and the general public living around the sites. Fatalities and injuries to involved workers who are near the accident site when an accident occurs are possible from all accidents (see Section 4.3.2.1).

At the three current storage sites, the potential cylinder accidents that could result in a release would be the same as the accidents discussed for the no action alternative. The estimated consequences of cylinder accidents at the current storage sites are discussed in Section 5.1.1.2.2.

At a conversion site, potential accidents could result in releases of depleted UF_6 from cylinders (a small inventory of cylinders would be temporarily stored at the conversion site awaiting processing). In addition, accidents involving releases of chemicals, such as ammonia and HF, would be possible. Ammonia is required for conversion, and HF is produced as a conversion by-product. The potential consequences of conversion accidents are discussed below and in detail in Appendix F.

The estimated consequences of conversion facility accidents are summarized in Table 5.4 for chemical effects and in Table 5.5 for radiation effects. The impacts are presented separately for accidents considered likely (defined as accidents with an estimated frequency greater than once per 100 years) and for those rare, low-probability accidents estimated to result in the largest potential impacts. Although other accidents were evaluated, including those at a long-term storage site, the consequences of other accidents would be less than those summarized in the tables. The consequences presented are conservative because they are based on the assumption that the wind would be blowing in the direction of the greatest number of people at the time of the accident and that weather conditions would limit dispersion in the air, resulting in high concentrations. In addition, the effects of protective measures, such as evacuation, were not considered. The actual consequences of accidents would be expected to be less than those discussed.

Chemical Effects. The potential consequences from chemical exposures of all conversion accidents considered likely to occur (i.e., a frequency greater than once per 100 years) would be zero adverse effects among members of the general public (Table 5.4); the off-site concentrations of chemicals released and transported downwind were estimated to be below levels causing adverse chemical health effects.

Noninvolved workers at a conversion site could be affected by chemical releases from accidents considered likely. The likely accident estimated to result in the greatest total number of adverse chemical effects among noninvolved workers is the failure of a corroded cylinder, spilling part of its contents under dry weather conditions. Such an accident could occur, for example, during handling of the cylinders. An estimated 24 lb (11 kg) of UF_6 could be released in such an accident. If this accident occurred at a conversion facility, it was estimated that up to 240 noninvolved workers might suffer potential adverse effects from exposure to HF and uranium (mostly mild and transient effects, such as respiratory irritation or temporary decrease in kidney function). The number of affected noninvolved workers for the same accident is greater at the conversion facility than at the current storage sites (Table 5.1) because of the number and closer proximity of the workers at the conversion facility. A different accident was estimated to result in the greatest potential number of irreversible adverse effects among noninvolved workers. The likely conversion accident estimated to result in the greatest total number of irreversible adverse effects would be an accident involving the release of ammonia vapor from a stripping column. If such an accident occurred, up to 40 noninvolved workers might experience irreversible adverse effects (such as organ damage). Exposure to ammonia is expected to cause death in about 2% of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Therefore, 1 noninvolved worker fatality was estimated if the accident occurred (2% of 40).

TABLE 5.4 Estimated Consequences of Chemical Exposures for Accidents under the Long-Term Storage as Oxide Alternative[a]

Receptor[b]	Accident Scenario	Activity	Accident Frequency Category[c]	Effect[d]	Consequence[e] (persons affected)
			Likely Accident(s)		
General public	All accidents	Conversion	L	Adverse effects	0
	All accidents	Conversion	L	Irreversible adverse effects	0
	All accidents	Conversion	L	Potential fatalities	0
Noninvolved workers	Corroded cylinder spill, dry conditions	Conversion	L	Adverse effects	240
	Ammonia stripper overpressure	Conversion	L	Irreversible adverse effects	40
	Ammonia stripper overpressure	Conversion	L	Potential fatalities	1
			Low Frequency-High Consequence Accident(s)		
General public	HF tank rupture	Conversion	I	Adverse effects	41,000
	Ammonia tank rupture	Conversion	I	Irreversible adverse effects	1,700
	Ammonia tank rupture	Conversion	I	Potential fatalities	30
Noninvolved workers	HF tank rupture	Conversion	I	Adverse effects	1,100
	Corroded cylinder spill, wet conditions – water pool	Conversion	EU	Irreversible adverse effects	440
	Corroded cylinder spill, wet conditions – water pool	Conversion	EU	Potential fatalities	4

a The accidents listed are those estimated to result in the greatest impacts among all the accidents considered. The impacts for a range of accidents at a conversion facility are listed in Appendix F.

b Noninvolved workers are persons working at the site but not involved in hands-on depleted UF_6 management activities. Depending on the circumstances of the accident, injuries and fatalities among involved workers are possible for all accidents.

c Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/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 Potential adverse effects include exposures that could result in mild and transient injury, such as respiratory irritation. Potential irreversible adverse effects include exposures that could result in permanent injury (e.g., impaired organ function) or death. The majority of the adverse effects would be mild and temporary in nature. For HF exposures, it is estimated that less than 1% of the predicted potential irreversible adverse effects would result in fatalities. For exposures to ammonia, it is estimated that about 2% of the predicted irreversible adverse effects would result in fatalities.

e The consequence is expressed as the maximum number of individuals with the predicted exposure level sufficient to cause the corresponding health endpoint. The estimated consequences were based on the assumption that the meteorological conditions would be F stability with 1 m/s wind speed, considered to be the worst conditions, and that the wind would be blowing in the direction of the highest worker or public population density.

TABLE 5.5 Estimated Consequences from Radiation Exposures for Accidents under the Long-Term Storage as Oxide Alternative[a]

				MEI		Population	
Receptor[b]	Accident Scenario	Activity	Accident Frequency Category[c]	Dose (rem)	Lifetime Risk of LCF	Dose (person-rem)	Number of LCFs
			Likely Accident(s)				
General public	Corroded cylinder spill, dry conditions	Conversion	L	0.0023	1×10^{-6}	0.3	0.0002
Noninvolved workers	Corroded cylinder spill, dry conditions	Conversion	L	0.077	3×10^{-5}	7.1	0.003
			Low Frequency-High Consequence Accident(s)				
General public	Earthquake	Conversion	EU	0.27	0.0001	20	0.01
Noninvolved workers	Earthquake	Conversion	EU	9.2	0.004	840	0.3

[a] The accidents listed are those estimated to have the greatest impacts among all accidents considered. The impacts for a range of accidents at a conversion facility are listed in Appendix F. The estimated consequences were based on the assumption that the wind would be blowing in the direction of the highest worker or public population density and that weather conditions would limit dispersion.

[b] Noninvolved workers are persons working at the site but not involved in hands-on depleted UF_6 management activities. Depending on the circumstances of the accident, injuries and fatalities among involved workers are possible for all accidents.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/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).

The engineering analysis report (LLNL 1997a) gave the frequency of likely accidents as greater than once in every hundred years; for assessment purposes, the specific frequency of likely accidents was assumed to be about once in 10 years (0.1 per year). Therefore, over a 20-year operational period, about 2 such accidents would be expected. Over the operational period of the conversion facility, the maximum accident risk (defined as consequence times probability) of likely accidents would be about 480 noninvolved workers with potential adverse effects and 80 noninvolved workers with potential irreversible adverse effects. The risk of fatalities would be about 2% of the 80 irreversible adverse effects, or about 2 fatalities. The number of noninvolved workers actually experiencing these effects would probably be considerably smaller, depending on the actual circumstances of the accident and the individual chemical sensitivity of the workers.

Conversion accidents that are less likely to occur could have much greater consequences. These rare accidents (low probability of occurrence) could cause adverse effects among both workers and members of the general public living around a conversion facility.

The conversion accident estimated to result in the greatest potential number of adverse chemical effects to members of the general public would be an accident involving rupture of an HF tank. In this accident, a tank was assumed to be ruptured by an earthquake or other major event, releasing about 8,000 lb (3,600 kg) of anhydrous HF. The occurrence of such an accident is considered incredible, expected to occur less than once in 1 million years. If this accident did occur, it was estimated that up to 41,000 members of the general public might experience adverse effects from HF exposure, mostly mild and transient effects such as respiratory irritation. A different accident, also considered incredible, was estimated to result in the greatest number of potential irreversible adverse effects among the general public. An ammonia tank rupture, caused by an earthquake, was assumed to release about 120,000 lb (55,000 kg) of ammonia. If such an accident were to occur, it was estimated that up to 1,700 members of the general public could experience irreversible adverse effects such as organ damage (the HF tank rupture accident would cause fewer than 1,700 irreversible effects). Exposure to ammonia would be expected to cause death in about 2% of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Therefore, about 30 fatalities could occur (2% of 1,700).

Rupture of an HF tank would also cause the greatest potential number of adverse effects among noninvolved workers. An HF tank rupture could cause up to 1,100 noninvolved workers to experience adverse effects, mostly mild and transient effects such as respiratory irritation. However, a corroded cylinder spill accident (under wet conditions) was estimated to result in the greatest potential number of irreversible adverse effects among conversion facility workers. This accident is considered extremely unlikely, expected to occur between once in 10,000 years and once in 1 million years. If this accident occurred, it was estimated that up to 440 noninvolved workers might experience irreversible adverse effects (such as lung damage) from exposure to HF and uranium. For HF exposure, the number of fatalities would be expected to be less than 1% of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Thus, about 4 fatalities among noninvolved workers could occur (1% of 440).

Although these accidents could have serious consequences to workers and members of the general public, they would not be expected to occur during the lifetime of the conversion facility. The most likely number of people (both workers and the general public) who would suffer from an irreversible adverse health effect or fatality as a result of one of these accidents is estimated to be zero (calculated by be multiplying the consequence times the probability of these accidents).

Radiation Effects. Potential conversion accidents could release uranium, which is radioactive in addition to being chemically toxic. Uranium could be released as UF_6 from cylinders or as uranium oxide. For conversion accidents, the potential impacts from radiation exposures were estimated to be much less than the impacts from chemical exposures. The radiation impacts from potential conversion accidents are given in Table 5.5. For all conversion accidents considered, the radiation doses from released uranium were estimated to be considerably below levels likely to cause radiation-induced effects among noninvolved workers and members of the general public and below the 25-rem dose recommended by the NRC (1994a) for assessing the adequacy of protection of public health and safety from potential accidents.

The accident considered likely (i.e., a frequency greater than once in 100 years) that would have the largest consequences from radiation exposures would be a corroded cylinder spill accident (dry conditions). If this accident occurred, the radiation dose to a maximally exposed member of the general public was estimated to be less than 3 mrem, resulting in an increased risk of death from cancer of about 1 in 1 million. The total population dose to the general public within 50 miles (80 km) was estimated to be less than 1 person-rem, estimated to most likely result in zero LCFs. Among noninvolved workers, the dose to an MEI was estimated to be 77 mrem, resulting in an increased risk of death from cancer of about 1 in 30,000. The total dose to all noninvolved workers was estimated to be about 7.1 person-rem. This dose to workers was estimated to most likely result in zero LCFs.

The potential conversion accident estimated to result in the largest estimated radiation doses would be an earthquake releasing uranium from an oxide storage building. This accident is considered extremely unlikely, expected to occur between once in 10,000 years and once in 1 million years. If this accident occurred, the radiation dose to a maximally exposed member of the general public was estimated to be about 270 mrem, resulting in an increased risk of death from cancer of about 1 in 10,000. The total population dose to the general public within 50 miles (80 km) was estimated to be 20 person-rem, most likely resulting in zero LCFs. Among noninvolved workers, the dose to an MEI was estimated to be about 9 rem (9,000 mrem), resulting in an increased risk of death from cancer of about 4 in 1,000. The total dose to all noninvolved workers was estimated to be about 840 person-rem. This dose to workers was estimated to most likely result in zero LCFs.

5.3.2 Transportation

Long-term storage as oxide could potentially require the shipment of both radioactive material and chemicals. The major materials assumed to be transported are summarized in Table 5.6. Potential materials transported include depleted UF_6 cylinders, uranium oxide, chemicals required for conversion, and products of conversion. In addition, some shipments of LLW and LLMW produced during processing would be required. 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. Because the locations of conversion and long-term storage sites will be evaluated in Phase II studies and NEPA reviews, for purposes of comparison, it was assumed that all shipments would travel a distance of 620 miles (1,000 km), primarily through rural areas but including some suburban and urban areas. The transportation assumptions and estimated impacts for a range of shipment distances are discussed in detail in Appendix J.

TABLE 5.6 Summary of the Major Materials Assumed to Be Transported, Estimated Number of Shipments, and Estimated Number of Traffic Accident Fatalities under the Long-Term Storage as Oxide Alternative, 1999 through 2039[a]

			Approximate Total Number of Shipments[b]		Estimated Traffic Accident Fatalities[c]	
Material	Origin	Destination	Truck	Rail	Truck	Rail
UF_6 cylinders	Current storage sites	Conversion site	46,422	11,600[d]	2	1
Uranium oxide (U_3O_8 or UO_2)	Conversion site	Long-term storage site	25,500 – 26,800	8,480 – 8,960	1	1
Ammonia	Supplier	Conversion site	520 (U_3O_8 conversion)	960 – 1,120 (UO_2 conversion)	0	0
Anhydrous HF (if produced)	Conversion site	User	–	4,860	0	0
CaF_2 (if HF neutralized)	Conversion site	User or disposal site	19,800	7,300	1	0
LLW/LLMW	Current storage/ conversion sites	Treatment/disposal site	900 - 2,360	–	0	0

[a] All materials were assumed to be transported to provide a conservative estimate of transportation impacts. A hyphen (–) denotes mode not considered for that material. Collocation of facilities would reduce transportation requirements.

[b] Estimated number of shipments when either the truck or rail mode is assumed to be used.

[c] Number of estimated traffic accident fatalities when each shipment is assumed to travel 620 miles (1,000 km) and national average accident statistics are used. Estimates have been rounded to the nearest whole number.

[d] Number of railcars, each containing four cylinders.

The transportation assessment was intended to provide a conservative estimate of the potential impacts that could occur. Therefore, it was assumed that all depleted UF_6 cylinders (46,422) would be transported from the three current storage sites to an independent conversion facility. Approximately 11,600 railcar shipments (four cylinders per railcar) or 46,422 truck shipments (one cylinder per truck) would be required. Furthermore, following conversion, the uranium oxide (either U_3O_8 or UO_2) was assumed to be packaged into drums and transported to a long-term storage facility. If all the UF_6 were converted, shipment of the oxide produced would require about 26,000 truck shipments or 9,000 railcar shipments. Collocating conversion and long-term storage facilities would minimize the potential amount of transportation required.

Conversion to oxide might require and might produce chemicals that could have adverse health impacts if accidentally released, primarily ammonia and anhydrous HF. Both ammonia and HF are potentially toxic chemicals commonly transported as liquids in trucks and rail tank cars. Depending on the conversion process, about 500 truck shipments of ammonia to a U_3O_8 conversion facility and up to about 1,100 rail shipments of ammonia to a UO_2 conversion facility would be required over the 20-year operational period. Anhydrous HF could be produced as a by-product of conversion and could be transported to a user. Up to about 5,000 railcars of anhydrous HF would be produced if all the UF_6 were converted to oxide. Alternatively, the HF could be neutralized to CaF_2, a nontoxic solid, at the conversion site. The CaF_2 could also be transported to a user or shipped for disposal.

5.3.2.1 Normal Transportation (Incident-Free) Operations

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

The total impacts during normal operations were estimated by assuming that all the cylinders, uranium oxide, process chemicals, and by-products required or produced would be shipped 620 miles (1,000 km). During normal operations, a total of 0 fatalities was estimated among workers and members of the general public, combined, if rail shipments were used, and 1 fatality was estimated if truck shipments were used. Rail transport results in smaller overall impacts because fewer shipments would be required. There would be no difference in impacts from the transportation of U_3O_8 or UO_2. Members of the general public living along truck and rail transportation routes were estimated to receive less than 0.1 mrem, even if a single person were to be exposed to every shipment of radioactive material during the program.

5.3.2.2 Transportation Accidents

Transportation accidents could occur during the transportation of radioactive materials and chemicals. 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 radioactive material or chemicals from a shipment.

5.3.2.2.1 Traffic Accidents with No Release

All shipments could be involved in truck or rail traffic accidents, with a chance that fatalities could result. Historical traffic accident statistics were used to predict the number of traffic fatalities that might result from future shipments. The expected number of traffic fatalities depends on the total number of shipments, the shipment distance, the shipment mode (truck or rail), and the historical accident fatality rates.

The total numbers of traffic fatalities were estimated by assuming that all the cylinders, uranium oxide, process chemicals, and by-products required or produced would be shipped 620 miles (1,000 km) by either truck or rail (see Table 5.6). If truck shipments were used, an estimated 4 traffic fatalities could result; if rail shipments were used, an estimated 2 traffic fatalities could result. Rail transport would result in a lower number of estimated traffic fatalities, primarily because railcars have a larger shipment capacity than trucks, resulting in fewer shipments. The actual number of fatalities would be much less if the number of shipments and shipment distances were reduced.

5.3.2.2.2 Traffic Accidents Involving Releases of Radiation or Chemicals

In most accidents, the radioactive material or chemicals being shipped would remain in the transport packages. However, in severe accidents, there is a potential for serious consequences if releases of anhydrous HF, ammonia, and depleted UF_6 (from cylinders) were to occur. If accidentally released, anhydrous HF and ammonia were estimated to have the greatest potential consequences of the materials that might require transportation. The consequences and risks of transportation accidents involving UF_6 cylinders are discussed in Section 5.2.2.2. Severe accidents involving the shipment of uranium oxide could also result in adverse effects from exposure to radiation, although the effects would be considerably less adverse than the consequences of UF_6 cylinder accidents (see Appendix J).

During the shipment of HF or ammonia, a severe accident could cause a release to the air from a truck or railcar. The amount released would depend on the severity and conditions of the accident. The material released could be dispersed downwind, potentially exposing members of the general public to chemical effects. The consequences would depend on the material released, the amount released, the location of the accident, and the weather conditions at the time. Potential consequences would be greatest in urban areas because more people could be exposed. Accidents that occurred when the weather was very stable (typical of nighttime conditions) would have higher potential consequences than accidents that occurred when the weather was unstable (i.e., turbulent, typical of daytime conditions). The consequences would be greater under stable conditions because the stability of the weather would determine how quickly the released material was dispersed and diluted to lower concentrations as it moved downwind.

The accident estimated to have the highest potential consequences would be a severe rail accident involving a release from a railcar containing anhydrous HF. The consequences of such an accident were estimated on the basis of the assumption that the accident occurred in an urban area under stable weather conditions (such as at nighttime). The probability of such an accident would depend on the total number of shipments, the distance between the origin and destination sites, and the characteristics of the route. For conversion of the entire UF_6 inventory to oxide, the amount of anhydrous HF produced could be enough to fill about 5,000 railcars. On the basis of assuming that each shipment would travel 620 miles (1,000 km) and using the national average accident statistics for railcars and representative route characteristics, the probability of an accidental HF release in an urban area would be about 1 in 30,000 (3×10^{-4}). If the HF were neutralized to CaF_2, no shipments of HF would be required.

If a large HF release from a railcar occurred in an urban area under stable weather conditions, persons within a 7 mi^2 (18 km^2) area downwind of the accident site (including crew members) could potentially suffer irreversible adverse effects from chemical exposure to HF. In a densely populated urban area, it was estimated that up to 30,000 persons might experience irreversible adverse effects such as lung damage. The number of fatalities following HF exposure would be expected to be somewhat less than 1% of the number of potential irreversible adverse effects (Policastro et al. 1997). Thus, up to 300 fatalities could occur (1% of 30,000). If the same type of HF rail accident were to occur in a typical rural area, which would have a smaller population density than an urban area, potential impacts would be considerably less. In a rural area, it was estimated that approximately 100 persons might experience irreversible adverse effects, resulting in about 1 fatality.

The weather conditions at the time of an accident would also significantly affect the expected consequences of a severe HF accident. The consequences of an HF rail accident would be much smaller under unstable weather conditions, the most likely conditions in the daytime. Unstable weather conditions would result in more rapid dispersion of the airborne HF plume and in lower downwind concentrations. Under unstable conditions, a downwind area of about 1 mi^2 (2 km^2) could be affected by a railcar accident. In such a case, approximately 3,000 persons were estimated to potentially experience irreversible adverse effects, including about 30 fatalities, if the accident occurred in an urban area. If the accident occurred in a rural area during unstable weather conditions, 10 persons were estimated to potentially experience irreversible adverse effects, with less than 1 fatality.

The estimated probability of occurrence of this accident in an urban area is about 0.00003. Therefore, at most, one individual would be estimated to experience an irreversible adverse effect because of this accident over the 20-year shipping period (calculated by multiplying the probability [0.00003] times the consequence [30,000] for an urban area under stable weather conditions). The number of fatalities estimated over the same period would be zero (1% of 1).

Another way to interpret the risk posed by an HF accident is to examine the risk of potential irreversible adverse effects to a specific individual who lived along a transportation route. Following a severe accident under stable weather conditions (which would result in the highest concentrations and consequences), HF air concentrations high enough to cause potential irreversible adverse effects could extend as far as 12 miles (20 km) downwind in a narrow band covering approximately 7 mi^2 (18 km^2). Therefore, an individual living near a route could be affected by an accident that occurred up to approximately 12 miles (20 km) in either direction (although the wind would have to be blowing in the direction of the individual). If all 5,000 HF shipments were along the same route, the probability of a severe HF accident occurring within 12 miles (20 km) in either direction of an individual near the route would be about 0.0005 (1 chance in 2,000) based on national statistics for severe accidents. However, the risk of the individual suffering potential irreversible adverse effects as a result of the accident would actually be less than 1 chance in 2,000 because the estimate was based on the assumption that the wind was blowing in the direction of the individual under stable weather conditions (the wind could be blowing in any direction and stable conditions occur, on average, about one-sixth of the time in the United States).

The consequences discussed for anhydrous HF accidents are meant to provide a conservative estimate of potential impacts. To provide perspective, anhydrous HF is routinely shipped commercially in the United States for industrial applications. Since 1971, the period covered by DOT records (Process Safety Engineering, Inc. 1994), there have been no fatal or serious injuries to members of the general public or to transportation or emergency response personnel as a result of anhydrous HF releases during transportation. Over that period, 11 releases from railcars (only one since 1985) have been reported. The amounts of HF released in these incidents were less than 1% of the shipment contents, except in one case. The only major release occurred in 1985 and resulted in approximately 100 minor injuries. The last HF release during transportation was a minor release in 1990. The improved safety record of transporting anhydrous HF in the past 10 years may be attributed to such practices as installing protective devices on railcars, an overall decline in the number of derailments, closer manufacturer supervision of container inspections, and participation of shippers in the Chemical Transportation Emergency Center (CHEMTREC).

Accidents involving ammonia could also result in severe consequences, but much less severe than those for the anhydrous HF accidents discussed above. Some conversion options could require up to about 1,000 railcar shipments over the duration of the program. On the basis of conservative assumptions, a severe railcar accident releasing ammonia in an urban area under stable weather conditions could result in up to 5,000 persons experiencing potential irreversible adverse effects. In a rural area, it was estimated that about 20 persons could experience potential irreversible adverse effects. However, because fewer shipments of ammonia than of anhydrous HF would be required, the risk associated with ammonia shipments would be less than the risk posed by anhydrous HF shipments. Exposure to ammonia would be expected to cause death in about 2% of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Therefore, up to 100 fatalities could occur (2% of 5,000) for an urban accident and less than 1 fatality for a rural accident (2% of 20). As discussed for anhydrous HF accidents, when the probability of occurrence of ammonia accidents is considered, the number of fatalities that could occur over the 20-year shipping campaign because of a severe ammonia accident was estimated to be zero. Ammonia is also commonly shipped in the United States for industrial applications.

Although accidents involving shipments of LLW and LLMW could occur, the consequences of the most severe accidents involving these materials would not be expected to cause any LCFs from radiation exposures or any irreversible adverse effects from exposure to chemicals.

5.3.3 Air Quality

The analysis of potential impacts on air quality for the long-term storage as oxide alternative considered the potential for air pollutant emissions from continued cylinder storage activities occurring through 2028, cylinder preparation activities, conversion, and long-term storage activities. For continued cylinder storage and cylinder preparation activities at the current sites, impacts would be identical to those discussed for the long-term storage as UF_6 alternative (Section 5.2.3).

At a conversion facility, air quality impacts would depend on the actual facility location; however, concentrations of criteria pollutants for the representative settings were all estimated to be within standards. Concentrations of PM_{10} during construction were estimated to be as high as 90% of the corresponding standard; procedures to reduce these emissions might have to be implemented during actual construction activities. Concentrations of the other criteria pollutants and HF were estimated to be less than 30% of respective standards during construction and less than 5% of respective standards during operations. An oxide conversion facility would emit between about 2 to 11 lb/yr (0.9 to 5 kg/yr) of uranium as either U_3O_8 or UO_2. No air quality standards exist for uranium compounds; however, potential health impacts of these emissions were evaluated in Section 5.3.1.1.

Concentrations of criteria pollutants and HF from a facility for long-term storage as oxide were estimated to be less than 12% of respective standards for all options.

5.3.4 Water and Soil

Water use during continued cylinder storage and cylinder preparation activities at the three current storage sites would be the same as that discussed in Section 5.2.4. At an oxide conversion facility, water use during construction would be between 4 and 12 million gal/yr; maximum water use during operations would be between 34 and 285 million gal/yr. Wastewater generation would range from about 15 to 140 million gal/yr.

For long-term storage in buildings, vaults, or a mine, water use during construction would be between 0.3 and 1.3 million gal/yr; maximum water use during operations would be about 1.4 million gal/yr. Wastewater generation would range from about 0.1 to 1.4 million gal/yr for all storage options. Impacts to surface water, groundwater, and soil are discussed in Sections 5.3.4.1 through 5.3.4.3.

5.3.4.1 Surface Water

Under the long-term storage as oxide alternative, potential impacts on surface water at the current storage sites during continued storage of the cylinders and cylinder preparation would be the same as those discussed for storage as UF_6 (Section 5.2.4.1). At an oxide conversion facility, impacts to surface water would depend on the actual location of the facility. However, an assessment of the representative settings considered in the PEIS indicates that impacts to runoff and floodplain encroachment would be negligible. Concentrations of uranium in effluents from a conversion facility would range from about 25 to 400 μg/L. After dilution in nearby surface water, concentrations probably would be much less than the 20 μg/L used as a guideline. Operation of any conversion facility would be contingent on meeting all applicable regulations and site-specific permit requirements.

Although dependent on the actual site location, impacts to runoff and floodplain encroachment during storage as oxide would probably be negligible. An assessment of the representative settings considered in the PEIS indicates that concentrations of uranium released in wastewater would be very low and would result in concentrations much lower than 20 μg/L in the surface waters to which wastewaters would be released.

5.3.4.2 Groundwater

Potential impacts on groundwater quality for continued cylinder storage through 2028 at the current storage sites are discussed in detail in Section 5.2.4.2. Conservative calculations indicated that uranium concentrations in groundwater directly below the sites could reach maximums of 20, 4, and 9 μg/L for the Paducah, Portsmouth, and K-25 sites, respectively. Groundwater directly beneath the surface contamination source would be unlikely to be used as a drinking water source; estimated maximum concentrations at 1,000 ft (305 m) downgradient were 16, 3, and 8 μg/L for the Paducah, Portsmouth, and K-25 sites, respectively. Potential groundwater impacts would be mitigated by collecting and treating runoff from the cylinder yards and by identifying and repairing breached cylinders as soon as possible. Impacts to groundwater from cylinder preparation would be none to negligible because no releases to groundwater would be expected during operations.

At an oxide conversion facility, the impacts to groundwater would depend on the actual location of the facility. However, an assessment of the representative settings considered in the PEIS indicates that impacts on recharge, depth to groundwater, or direction of flow would be negligible (the maximum increase over current groundwater use was estimated to be 5%). Because discharges to groundwater are not planned (facility effluents would be released to nearby surface waters), there would be no direct impacts to groundwater quality.

For storage as oxide, the potential impacts to groundwater would also depend on the actual location. Potential impacts during construction would include groundwater contamination with construction chemicals. By adopting good engineering practices (e.g., covering material to prevent interaction with rain and promptly cleaning any chemical spills), the potential for adverse impacts to groundwater would be minimized. During operations, impacts to groundwater would be negligible because the building, vault, or mine would isolate contaminants released during normal operations.

5.3.4.3 Soil

Potential impacts on soil from continued cylinder storage through 2028 and from cylinder preparation activities at the current storage sites would be the same as those discussed in Section 5.2.4.3. Impacts on soil at conversion and long-term storage facilities would depend on the facility location. Potential impacts, which would tend to be temporary, would generally result from material excavated during construction that would be left on-site. The largest potential impacts on soil would occur for long-term storage in a mine. Construction of a mine for storage could require excavating between about 1.2 and 2.2 million yd^3 (930,100 to 1.7 million m^3) of consolidated material. In the short term, this amount of material would cause changes in site topography. In the long term, contouring and reseeding would return soil conditions back to their former state, and the impacts would be minor. If a previously existing mine were used for storage, excavation requirements could be significantly reduced, and potential impacts on soil would be much smaller. Potential impacts on soil from a conversion facility or from storage in buildings or vaults would be minor and temporary, much smaller than from storage in a mine.

5.3.5 Socioeconomics

Potential socioeconomic impacts at the current storage sites from continued cylinder storage through 2028 and cylinder preparation activities are discussed in Section 5.2.5. No significant impacts to ROI employment and population growth rates, vacant housing, or public finances would be expected.

The potential socioeconomic impacts of construction and operation of an oxide conversion facility (including impacts from cylinder treatment) would depend on the facility location. Construction activities would create short-term employment (340 to 730 direct jobs and 560 to 1,600 total jobs in the peak construction year); operational activities would create from 330 to

490 direct jobs and from 700 to 1,500 total jobs per year. Direct and total income from construction in the peak year would be from $16 to $33 million and from $19 to $48 million, respectively. During operations, direct and total income would be between $20 and $28 million/yr and from $27 to $42 million/yr, respectively. For the representative settings used for analysis, the employment and income created would represent a change of less than 0.1% of projected growth in these indicators of overall regional activity. The in-migration expected into the region containing an oxide conversion facility would have only a small impact on regional population growth rates. A moderate impact to housing could occur, with about 30% of the projected number of vacant rental housing units in the representative ROIs being required. Small impacts on local public finances would be expected, with all increases over forecasted baseline revenues and expenditures being less than 1%.

The potential socioeconomic impacts of construction and operation of a long-term storage facility would depend on facility location, oxide form (U_3O_8 or UO_2), and whether buildings, vaults, or a mine was selected. Construction activities would create employment (120 to 410 direct jobs in the peak construction year); operational activities would create from 60 to 70 direct jobs per year. Direct income from construction in the peak year would range from $5 to $20 million. During operations, direct income would range from $3 to $4 million/yr. For long-term storage, construction and operations would be occurring concurrently over the 20-year emplacement period.

For the representative settings used for analysis of building and vault options, the employment and income created would represent a change of less than 0.02% of projected growth in these indicators of overall regional activity (see Appendix G, Section G.3.5). The in-migration expected into the region containing an oxide storage facility would have only a small impact on regional population growth rates. Negligible impacts on local public finances would be expected. The impacts for mine storage were calculated for a generic site; therefore, no estimates of indirect impacts on employment and income were made for mine options.

5.3.6 Ecology

Potential ecological impacts of continued storage and cylinder preparation at the current storage sites would be the same as those discussed in Section 5.2.6. For conversion and long-term storage facilities, construction would disturb about 30 to 40 acres (12 to 16 ha) for conversion, 120 to 210 acres (49 to 85 ha) for long-term storage as U_3O_8, and 75 to 110 acres (30 to 45 ha) for long-term storage as UO_2. Existing vegetation at the conversion and long-term storage sites would be destroyed during land-clearing activities. In addition, wildlife would be disturbed by land clearing, noise, and human presence. The extent of the impacts on ecological resources would depend on the locations of the facilities; however, some permanent loss of habitat could result. Impacts to wetlands and state and federally protected species due to facility construction would also depend on the facility locations. Avoidance of wetland areas would be included during facility planning, and site-specific surveys for protected species would be conducted prior to finalization of facility siting plans.

Impacts to ecological resources from facility operations at a conversion or long-term storage site would be negligible to small. The concentrations of radioactive and chemical contaminants in air and water emissions would be considerably below levels considered harmful to vegetation and wildlife.

Facility and transportation accidents (see Sections 5.3.1 and 5.3.2) 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 accident, season, and meteorological conditions.

5.3.7 Waste Management

The impacts on waste management operations from continued storage and cylinder preparation activities at the current sites through 2028 would be the same as those discussed in Section 5.2.7. The operation and construction of a conversion facility would also generate radioactive, hazardous, and sanitary solid wastes. Construction of U_3O_8 and UO_2 conversion facilities would generate a maximum of approximately 115 and 200 m^3, respectively, of hazardous waste. Conversion to U_3O_8 would generate about 140 to 600 m^3/yr of LLW, 1 m^3/yr of LLMW, and 7 m^3/yr of hazardous waste during operations. Conversion to UO_2 would generate about 170 to 740 m^3/yr of LLW, 0 to 18 m^3/yr of LLMW, and 7 to 17 m^3/yr of hazardous waste during operations (ranges are the result of assessing different conversion technologies).

During conversion, nonhazardous solid waste and wastewater generation rates could exceed the current rates at the representative settings considered in the analysis, but the actual facilities would be designed to meet appropriate waste treatment demands. Under the various oxide conversion options, CaF_2 could be produced. It is currently unknown whether this CaF_2 would be sold; whether its low uranium content would allow it to be disposed of as nonradioactive, nonhazardous solid waste; or whether it would have to be disposed of as LLW. The projected low level of uranium contamination (i.e., less than 1 ppm) suggests that sale or disposal as nonradioactive, nonhazardous solid waste would be most likely. If disposed of as nonradioactive, nonhazardous solid waste, approximately 380 to 11,000 m^3/yr would be generated, which would be 18 to 500% of current nonradioactive, nonhazardous solid waste loads at the representative settings; such an increased input could be managed by expanding the capacity for sanitary waste disposal at an actual conversion facility. If CaF_2 were considered to be LLW, it would probably have to be stabilized through grouting prior to disposal, increasing the volume to 21,300 m^3/yr for 20 years. This volume of LLW (up to 426,000 m^3 total) would represent about 10% of the projected DOE complexwide LLW disposal volume for approximately the same time period (i.e, 4.25 million m^3; see Appendix C, Section C.10). Disposal of CaF_2 as LLW could result in moderate impacts for waste management, if the LLW were considered to be DOE waste. Overall, the waste input resulting from normal operations at a conversion facility might have a moderate impact on waste management operations.

Conversion would also require construction and operation of a cylinder treatment facility. Construction of a cylinder treatment facility would generate about 18 m^3 of hazardous waste.

Operation of the treatment facility would generate about 48 m^3/yr of LLW, 0.2 m^3/yr of LLMW, and 2 m^3/yr of hazardous waste; these volumes represent negligible impacts to the waste management system. These volumes exclude the crushed cylinders, which would represent a volume of about 6,200 m^3/yr. It was assumed that the treated crushed cylinders would become part of the DOE scrap metal inventory. If a decision for disposing of the crushed cylinders was made, the treated cylinders would be disposed of as LLW, representing a 3% addition to the projected DOE complexwide LLW disposal volume.

The operation and construction of a long-term oxide storage facility would also generate radioactive LLW and nonradioactive, nonhazardous solid wastes. The generation of LLW would result from the repair or repackaging of failed storage containers (i.e., drums). The long-term storage as oxide alternative would generate a maximum of approximately 20 m^3 of LLW for storage in buildings, vaults, or a mine.

Compared with national and regional waste management capabilities (see Appendix C), the generation of waste under the long-term storage as oxide alternative would have a negligible to moderate impact.

5.3.8 Resource Requirements

Construction and operation of conversion and long-term storage facilities would consume electricity, fuel, concrete, steel and other metals, and miscellaneous chemicals that are generally irretrievable resources. The total quantity of commonly used materials is not expected to be significant for conversion or storage for both U_3O_8 and UO_2 and would not affect local, regional, or national availability of these materials. Small to moderate amounts of specialty materials (i.e., Monel, Inconel, and titanium) would be required for construction of conversion facilities; no specialty materials would be required for construction or operation of a long-term storage facility. In general, facility operational requirements are not resource intensive, and the resources required are not considered rare or unique. However, for storage in a mine, large quantities of electrical energy would be required during construction (up to 1,000 MW-yr) because the majority of the construction equipment required to build the underground portion would be powered by electricity. The impact of this high electrical requirement on local energy resource use would depend on the location of the facility and the existing infrastructure. If a previously existing mine were used for storage, excavation and construction requirements would probably be reduced, and, depending on the characteristics and condition of the mine, the electrical requirements might also be reduced.

5.3.9 Land Use

Potential impacts for continued storage and cylinder preparation at the current storage sites would be the same as those discussed in Section 5.2.9. Impacts on land use for conversion and long-term storage facilities would depend on the locations of the facilities. The amount of land required would range from about 30 to 40 acres (12 to 16 ha) for conversion, 120 to 210 acres (49 to 85 ha) for long-term storage as U_3O_8, and 75 to 110 acres (30 to 45 ha) for long-term storage as UO_2, constituting potential land use impacts ranging from negligible to moderate. A protective action distance for emergency planning would need to be established around a conversion facility. This protective action distance would incorporate an area of about 960 acres (380 ha) around the facility. For storage in a mine, on-site topographical modifications associated with the disposition of excavated material could potentially affect future on-site land use. The potential for such impacts would be evaluated in the Phase II analyses and NEPA reviews. Impacts to land use outside the boundaries of facilities would be limited to temporary traffic impacts associated with construction.

5.3.10 Cultural Resources

Potential impacts to cultural resources during continued cylinder storage and cylinder preparation activities at the three current storage sites would be the same as those discussed in Section 5.2.10. The impacts to cultural resources for conversion and long-term storage facilities cannot be determined until the locations of the facilities are selected. However, impacts to cultural resources would be evaluated in Phase II studies and avoided if necessary and appropriate.

5.3.11 Environmental Justice

Potential environmental justice impacts from continued cylinder storage and cylinder preparation activities at the three current storage sites would be the same as those discussed in Section 5.2.11. Potential environmental justice impacts to minority and low-income populations from the construction and operation of conversion and long-term storage facilities would depend on the locations of these facilities. Moreover, because transportation routes are not currently known, and because it is impossible to reliably predict who would be involved in transportation accidents, there is no reason to believe that the impacts of transportation accidents will affect minority or low-income populations disproportionately.

5.4 USE AS URANIUM OXIDE

The use as uranium oxide alternative considers the use of 100% of the depleted UF_6 inventory. Under the use as uranium oxide alternative, it was assumed for assessment purposes that the depleted UF_6 would be converted to UO_2, which would be used in the manufacture of casks for storing spent nuclear fuel or HLW. (Although storage casks were assumed for assessment purposes, other uses for depleted uranium are possible). The uranium oxide in the storage casks would serve as radiation shielding. The casks would be transported to a user facility, such as a commercial nuclear power plant or DOE facility, where they would be used to store spent nuclear fuel or HLW. To provide a conservative estimate of potential transportation and construction impacts, the conversion, manufacturing, and use facilities were assumed to be at different locations. Issues associated with depleted uranium management after use are discussed in Section 5.9.

The following is a summary of the activities analyzed under the use as uranium oxide alternative:

- ***Continued Cylinder Storage (at Paducah, Portsmouth, and K-25).*** Depleted UF_6 cylinder storage would continue at each of the three current storage sites through 2028. The entire inventory would be stored at the sites through 2008, but the site inventory would decrease from 2009 through 2028 as cylinders were shipped to an independent conversion facility. The cylinder management activities that would occur at the sites were assumed to be similar to the no action alternative.

- ***Preparation of Cylinders for Shipment (at Paducah, Portsmouth, and K-25).*** Two cylinder preparation options were considered for cylinders not meeting transportation requirements: (1) a cylinder overcontainer option and (2) a cylinder transfer option (see Appendix E). The cylinder overcontainer option would not require the construction of any new facilities; for the cylinder transfer option, it was assumed that a transfer facility would be constructed at each of the three sites.

- ***Conversion (Representative Site).*** Conversion of UF_6 to an oxide, assumed to be UO_2 for assessment purposes, was assumed to occur from 2009 through 2028 at a newly constructed, stand-alone conversion facility.[2] As described in Appendix F, three representative conversion technologies were assessed for conversion to UO_2. The principal product of conversion would be either anhydrous HF, which would be shipped to a user facility, or CaF_2, which could be shipped for use or disposal.

- ***Transportation (Representative Routes).*** All UF_6 cylinders were assumed to be transported by either truck or rail from the Paducah, Portsmouth, and K-25 sites to an independent conversion site. Following conversion, the UO_2 produced was assumed to be transported in drums by truck or rail to a manufacturing site. In addition, HF or CaF_2 would require transportation to

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[2] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

either a user or disposal facility. The uranium-oxide-shielded casks were assumed to be transported by rail from the manufacturing facility to a user site.

- ***Manufacture and Use (Representative Site).*** The manufacture of uranium oxide shielded casks was assumed to take place at a stand-alone facility dedicated to the cask manufacturing process. Casks would be manufactured and sent to a user facility, such as a nuclear power plant or DOE facility, where they would be used to store spent nuclear fuel or HLW. Manufacturing was assumed to occur concurrently with conversion (i.e., from 2009 through 2028). Preoperation of manufacturing facilities would occur between 1999 and 2008 (with actual construction requiring 7 years).

During use of depleted-uranium-concrete casks, impacts would be expected to be negligible. No release of depleted uranium would be expected during use because the uranium would be a solid material encased between thick stainless steel shells. In addition, radiation emitted from the uranium shielding material would be shielded by the steel cask shells and would be negligible compared with the highly radioactive spent nuclear fuel or HLW contained within the casks during use. Finally, the use of a radiation shield implies that there would be a net benefit because the radiation levels would be reduced.

5.4.1 Human Health and Safety

During implementation of the use as oxide alternative, potential impacts to human health and safety could result from facility operations during both routine conditions and accidents. The principal facilities involved include the current storage sites, a conversion facility, and a cask manufacturing facility. Potential impacts are discussed in Sections 5.4.1.1 and 5.4.1.2.

5.4.1.1 Normal Facility Operations

5.4.1.1.1 Workers

The total radiation exposure of involved workers under the use as uranium oxide alternative would be greater than under the no action alternative because of the additional activities required for preparation of cylinders for shipment, conversion operations, and manufacture of oxide-shielded storage casks for use. At the three current storage sites, involved workers would be exposed to low-level radiation during routine cylinder monitoring and maintenance, cylinder relocation and painting, cylinder patching or repairing, and preparation of cylinders for shipment. Involved workers at a conversion facility would be exposed to radiation while handling incoming cylinders, during conversion operations, and while handling uranium oxide. At a cask manufacturing facility, involved workers would be exposed to radiation during the manufacture of casks. At all facilities, radiation exposure of workers would be maintained in accordance with ALARA practices.

The number of potential radiation-induced LCFs among involved workers from 1999 through 2039 was estimated to range from about 1 to 2, compared with 1 for the no action alternative. In addition to about 60 cylinder yard workers, between 290 and 470 involved workers would be required for the use as oxide alternative (the exact number would depend on the cylinder preparation and conversion options selected). Impacts to noninvolved workers would be negligible compared to those for the involved workers (i.e., less than 1% of the involved worker impacts).

Impacts to involved and noninvolved workers from exposure to chemicals during normal operations would not be expected. The workplace would be monitored to ensure that airborne chemical concentrations were within applicable health standards that are protective of human health and safety. If planned work activities were likely to expose involved workers to chemicals, they would be provided with appropriate protective equipment, as necessary. The potential chemical exposure of noninvolved workers from airborne releases during normal operations were estimated to be below levels expected to cause adverse effects (the estimated hazard indices were less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, and at a cask manufacturing facility).

5.4.1.1.2 General Public

The potential impacts to members of the general public during normal operations would be similar to the no action alternative — all exposures were estimated to be within applicable public health standards. No LCFs from radiation exposures and no adverse effects from chemical exposures were estimated to occur among members of the general public near the three current storage sites, near a conversion facility, or near a cask manufacturing facility from depleted UF_6 management activities. At the current storage sites, potential impacts to the members of the general public would be the same as described in Section 5.2.1.1.2 for the long-term storage as UF_6 alternative.

At an oxide conversion facility, members of the general public could potentially be exposed to small amounts of uranium and HF released to the air during normal operations. The total collective radiation dose to the general public from airborne emissions was estimated to range from about 2 to 10 person-rem over the operational period of the conversion facility (2009 through 2028). This range takes into account the different UO_2 conversion options and environmental settings considered (see Appendix F). This level of exposure was estimated to most likely result in zero LCFs among the general public. The maximum radiation dose to an individual near a UO_2 conversion site was estimated to be less than about 0.03 mrem/yr from airborne emissions, well within the applicable health standards (see Section 5.2.1.1.2). If an individual were to receive the maximum estimated dose every year the conversion facility operated (2009 through 2028), the total dose would be about 1 mrem, and the resulting chance of dying from a radiation-induced latent cancer would be less than 1 in 1 million. No noncancer health effects from exposure to airborne uranium and HF releases would be expected — the hazard index for an individual near a conversion facility was estimated to be less than 0.0002.

At a cask manufacturing facility, the potential exposure of members of the general public to radiation or chemicals was estimated to be much less than at a conversion facility. The total radiation dose to the general public (2009 through 2028) was estimated to be about 0.1 person-rem, which would be expected to most likely result in zero LCFs. The maximum radiation dose to an individual near a manufacturing site was estimated to be less than 0.001 mrem/yr from airborne emissions, well within the applicable health standards (see Section 5.2.1.1.2). No noncancer health effects from chemical exposures would be expected — the hazard index for an individual near a manufacturing facility was estimated to be less than 0.00001.

5.4.1.2 Facility Accidents

5.4.1.2.1 Physical Hazards (On-the-Job Injuries and Fatalities)

Accidents occur in all work environments. In 1994, about 5,000 work-related fatalities and 3.5 million work-related injuries were reported in the United States (National Safety Council 1995). Although all work activities would be conducted in as safe a manner as possible, there is a chance that workers could be accidentally killed or injured during the use as oxide alternative, unrelated to any radiation or chemical exposures.

The number of accidental worker injuries and fatalities that might occur from 1999 through 2039 were estimated on the basis of the number of workers required over this period and the historical accident fatality and injury rates in similar types of industries. The estimated number of worker fatalities and injuries would be greater than under the no action alternative because of the additional construction and operational activities required for cylinder preparation, conversion, and cask manufacturing facilities. The number of fatalities and injuries would depend on the specific cylinder preparation and conversion options.

Considering all conversion and manufacturing options, from 2 to 3 total accidental worker fatalities were estimated over the 41-year period. Approximately 1,300 to 2,000 injuries (defined as injuries resulting in lost workdays) were estimated from construction and operation of facilities over the same period. At the current storage sites, the maximum total number of injuries was estimated to be about 700, assuming that a cylinder transfer facility would be constructed and operated at each site. If cylinder overcontainers were used as the cylinder preparation option, a maximum of about 150 worker injuries were estimated at the three sites combined. Approximately 660 worker injuries were estimated to occur at a conversion facility (including treatment of empty cylinders), and approximately 640 worker injuries were estimated to occur at a cask manufacturing facility. These rates would not be unique to the activities required for the alternative, but would be typical of any industrial project of similar size and scope.

5.4.1.2.2 Accidents Involving Releases of Radiation or Chemicals

Under the use as oxide alternative, accidents potentially releasing radiation and chemicals could occur at the three current storage sites (during continued cylinder storage through 2028), at an oxide conversion site, and at a cask manufacturing site. At each site, a range of accidents was evaluated, from those considered reasonably likely to occur (once or more in 100 years on average) to those that would be extremely rare (expected to occur less than once in 1 million years on average). The accidents considered are described in Appendix D, Section D.2.2, for continued cylinder storage; Appendix F, Section F.3.2, for conversion; and Appendix H, Section H.3.2, for cask manufacturing.

The potential consequences of cylinder accidents at the current storage sites and accidents at an oxide conversion facility are described in Section 5.1.1.2.2 for the no action alternative and in Section 5.3.1.2.2 for the long-term storage as oxide alternative. Although the use as oxide alternative would involve only conversion to UO_2, compared to UO_2 and U_3O_8 for the long-term storage as oxide alternative, the only difference in the results of the accident assessment would be in the radiological consequences for an earthquake accident at a conversion facility. The consequences of that accident were estimated to be somewhat less at a UO_2 conversion facility than at a U_3O_8 conversion facility (see Appendix F, Tables F.8 and F.9).

At a uranium oxide cask manufacturing facility, the potential consequences of all the accidents considered were estimated to be much less than potential conversion or cylinder accidents (see Appendix H, Section H.3.2). For all cask manufacturing accidents, chemical exposures of noninvolved workers and members of the general public were estimated to be much less than levels expected to cause adverse effects. The radiation dose to a maximally exposed noninvolved worker from an accident was estimated to be about 80 mrem, with a corresponding risk of death from cancer of about 1 chance in 30,000 (0.00003). The dose to a maximally exposed member of the general public was estimated to be less than 3 mrem, considerably below the 25-rem dose recommended by the NRC (1994a) for assessing the adequacy of protection of public health and safety from potential accidents. The risk of death from cancer to an individual from this dose would be about 1 chance in 1 million. No LCFs were estimated to occur among noninvolved workers or members of the general public for the highest consequence accident evaluated. As described in Section 4.3.2.1, fatalities and injuries among involved workers are possible for all accidents.

5.4.2 Transportation

The major materials assumed to be transported under the use as oxide alternative are summarized in Table 5.7. The transportation activities for the use as oxide alternative would be very similar to those described for the long-term storage as oxide alternative in Section 5.3.2. For both alternatives, it was assumed that cylinders would be transported from the current storage sites to an oxide conversion facility. The two alternatives differ in the destination of the uranium oxide after conversion: it would be shipped either to a long-term storage facility or to a cask manufacturing

TABLE 5.7 Summary of the Major Materials Assumed to Be Transported, Estimated Number of Shipments, and Estimated Number of Traffic Accident Fatalities under the Use as Oxide Alternative, 1999 through 2039[a]

			Approximate Total Number of Shipments[b]		Estimated Traffic Accident Fatalities[c]	
Material	Origin	Destination	Truck	Rail	Truck	Rail
UF_6 cylinders	Current storage sites	Conversion site	46,422	11,600[d]	2	1
Uranium oxide (UO_2)	Conversion site	Manufacturing site	26,260 – 26,800	8,480 – 8,800	1	1
Ammonia	Supplier	Conversion site	–	960 – 1,120 (UO_2 conversion)	0	0
Anhydrous HF (if produced)	Conversion site	User	–	4,860	0	0
CaF_2 (if HF neutralized)	Conversion site	User or disposal site	19,800	7,300	1	0
LLW/LLMW	Current storage/ conversion/manu-facturing sites	Treatment/disposal site	1,220 – 2,680	–	0	0
Casks	Manufacturing site	User	–	9,600	–	0

[a] All materials were assumed to be transported to provide a conservative estimate of transportation impacts. A hyphen (–) denotes mode not considered for that material. Colocation of facilities would reduce transportation requirements.

[b] Estimated number of shipments assuming that either the truck or rail mode was used.

[c] Number of estimated traffic accident fatalities assuming each shipment traveled 620 miles (1,000 km) and using national average accident statistics. Estimates have been rounded to the nearest whole number.

[d] Number of railcars, each containing four cylinders.

facility. However, because the locations of future long-term storage and cask manufacturing sites will be decided in Phase II of the management program, in both cases the potential impacts from these shipments were estimated assuming a representative route of 620 miles (1,000 km). Although the long-term storage as oxide alternative would involve both U_3O_8 and UO_2, the transportation risks would be very similar for shipments of U_3O_8 and UO_2 (see Appendix J, Section J.3.5, Tables J.11 through J.14). Consequently, the estimated impacts from shipments of oxide under the use as oxide alternative are almost identical to the impacts discussed in Section 5.3.2 for the long-term storage as oxide alternative. Both alternatives would also require the transportation of essentially the same amounts of process chemicals (ammonia), products of conversion (anhydrous HF or CaF_2), and waste generated during processing. Thus, the potential impacts for shipments of these materials would be the same as those described in detail in Section 5.3.2 during both normal conditions and accidents.

In addition to the materials and impacts discussed in Section 5.3.2, the use as oxide alternative would also require the shipment of casks from the manufacturing facility to a user. These casks, because of their large size, were assumed to be shipped by rail. A maximum of about 9,600 railcar shipments would be required to transport all the casks to users. The risk associated with cask shipments would be from typical traffic accidents, unrelated to the depleted uranium contained in the casks (external radiation dose rates would be extremely low near a cask and only negligible releases of uranium would be expected in extremely severe accidents because the uranium would be a solid encased between steel shells). If the 9,600 casks were shipped by rail over a distance of 620 miles (1,000 km), it was estimated on the basis of rail accident statistics that less than 1 traffic fatality would result. For comparison, shipment of all the cylinders, uranium oxide, and associated materials was estimated to potentially result in between 2 and 4 traffic fatalities, depending on whether truck or rail shipments would be used (see Section 5.3.2). Consequently, the estimated overall risks from transportation for the use as oxide alternative are essentially the same as those described for the long-term storage as oxide alternative.

5.4.3 Air Quality

The analysis of potential impacts on air quality from the use as oxide alternative considered the potential for air pollutant emissions from continued cylinder storage activities occurring through 2028, cylinder preparation activities, conversion, and manufacturing activities. For continued cylinder storage and cylinder preparation activities at the current sites, impacts would be identical to those discussed for the long-term storage as UF_6 alternative (Section 5.2.3). At a conversion facility, air quality impacts would be the same as discussed under the long-term storage as oxide alternative (Section 5.3.3).

At a cask manufacturing facility, air quality impacts would depend on the actual facility location; however, concentrations of criteria pollutants were all estimated to be within standards at the representative sites considered. Concentrations of criteria pollutants were estimated to be less than 9% of standards during construction and operations. The oxide cask manufacturing facility would emit 0.02 lb/yr (0.008 kg/yr) of uranium as UO_2. No air quality standards exist for uranium compounds; however, the potential health impacts of these emissions were evaluated in Section 5.4.1.1.

5.4.4 Water and Soil

Water use from continued cylinder storage and cylinder preparation activities at the current storage sites would be the same as discussed in Section 5.2.4. At a conversion facility, water use would be the same as described in Section 5.3.4. At a cask manufacturing facility, water use during facility construction (duration of about 7 years) would be 35 million gal/yr, and water use during operations would be about 7.5 million gal/yr. Wastewater generation would range from about 5 million gal/yr during operations to 8 million gal/yr during construction.

5.4.4.1 Surface Water

Under the use as oxide alternative, potential impacts on surface water at the current storage sites during continued storage of the cylinders and cylinder preparation would be the same as discussed for storage as UF_6 (Section 5.2.4.1). At a conversion facility, potential impacts to surface water would be the same as discussed for long-term storage as oxide (Section 5.3.4.1).

At a cask manufacturing facility, water use and wastewater generation during operations would be less than half that required for a conversion facility. Impacts to surface water would depend on the actual location of the facility.

5.4.4.2 Groundwater

Potential impacts on groundwater quality for continued cylinder storage through 2028 and for cylinder preparation activities at the three current storage sites would be the same as discussed in Section 5.2.4.2. At a conversion facility, the potential impacts would be the same as discussed in Section 5.3.4.2. Groundwater impacts at a cask manufacturing facility would depend on the size of the site in comparison with the size of the facility, on the proximity of the site to a river with relatively large flow volume (i.e., large in comparison with annual water use and wastewater discharge), and on whether the manufacturing facility water would be drawn from a surface water source or from groundwater. Because discharges to groundwater are not planned for these facilities (effluents would be released to nearby surface waters), there would be no direct impacts on groundwater quality. Good engineering and construction practices would be followed to minimize the potential for adverse effects during construction.

5.4.4.3 Soil

Potential impacts on soil at the current storage sites and at a conversion facility would be the same as discussed in Sections 5.2.4.3 and 5.3.4.3, respectively. Potential impacts at a manufacturing facility would depend on the actual location of the facility. Depending on the location of facilities and the amount of land area available, construction activities could cause changes in site topography, permeability, erosion potential, and soil quality. However, mitigative actions (e.g., contouring and reseeding excavated material, construction of retention basins, and prompt cleanup of chemical spills) would probably result in negligible impacts to soil.

5.4.5 Socioeconomics

Potential socioeconomic impacts associated with continued cylinder storage through 2028 and with cylinder preparation activities at the three current storage sites are discussed in Section 5.2.5. Socioeconomic impacts for an oxide conversion facility are summarized in Section 5.3.5.

The potential socioeconomic impacts of construction and operation of an oxide cask manufacturing facility would depend on the facility location. Construction of a cask manufacturing facility would create 160 direct jobs and $7 million in direct income during the peak year of construction. Operation of the facility would create 470 direct jobs and produce $33 million in direct income in each year of facility operation.

5.4.6 Ecology

Potential ecological impacts of continued cylinder storage and cylinder preparation activities at the current storage sites would be the same as discussed in Section 5.2.6. Potential impacts at a conversion facility would be the same as discussed in Section 5.3.6.

A cask manufacturing facility would require about 90 acres (36 ha). Existing vegetation at the site would be destroyed during land-clearing activities. In addition, wildlife could be disturbed by land clearing, noise, and human presence. The extent of the impacts on ecological resources would depend on the location of the facility; in general, a loss of 90 acres would constitute a potential moderate adverse impact in terms of habitat loss. Impacts to wetlands and state and federally protected species due to facility construction would also depend on the facility location. Avoidance of wetland areas would be included during facility planning, and site-specific surveys for protected species would be conducted prior to finalization of facility siting plans.

Facility and transportation accidents (see Sections 5.4.1 and 5.4.2) 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 accident, season, and meteorological conditions.

5.4.7 Waste Management

The waste management impacts of continued cylinder storage and cylinder preparation at the current sites are discussed in Section 5.2.7; waste management impacts at a conversion facility, including treatment of empty cylinders, are discussed in Section 5.3.7.

The operation of a cask manufacturing facility would generate about 130 m^3/yr of LLW, 290 m^3/yr of hazardous waste, and 250 metric tons/yr of nonradioactive, nonhazardous solid waste; an additional 72 m^3 of hazardous waste and 60,000 m^3 of nonradioactive, nonhazardous solid waste would be generated during construction. The LLW generated would be only about 0.2% of the LLW projected annual treatment volume for all DOE facilities nationwide (i.e., 68,000 m^3/yr; see Appendix C, Section C.10).

5.4.8 Resource Requirements

Resource requirements for continued cylinder storage and cylinder preparation activities at the current storage sites are discussed in Section 5.2.8. Resource requirements for a conversion facility are discussed in Section 5.3.8. For a cask manufacturing facility, the total quantity of commonly used materials required for construction and operation would not be significant. Specialty materials would not be required. In general, facility operational requirements are not resource intensive and the resources required are not considered rare or unique.

5.4.9 Land Use

Land-use impacts from continued cylinder storage and cylinder preparation activities at the current storage sites are discussed in Section 5.2.9. Impacts on land use for conversion are discussed in Section 5.3.9. The amount of land required would be about 90 acres (36 ha) for a cask manufacturing facility, constituting potential moderate land use impacts. The potential for such impacts would be evaluated in the site-specific Phase II studies and NEPA reviews. Impacts to land use outside the boundaries of facilities would consist of potential temporary traffic impacts associated with project construction.

5.4.10 Cultural Resources

Potential impacts to cultural resources from continued cylinder storage and cylinder preparation activities at the three current storage sites are discussed in Section 5.2.10. The impacts to cultural resources for conversion and manufacturing facilities would depend on the specific locations of the facilities. Impacts to cultural resources would be evaluated in Phase II studies and avoided as necessary and appropriate.

5.4.11 Environmental Justice

Potential environmental justice issues related to continued cylinder storage and cylinder preparation activities at the current storage sites would be the same as those discussed in Section 5.2.11 for the long-term storage as UF_6 alternative. Potential environmental justice impacts to minority and low-income populations from the construction and operation of conversion and manufacturing facilities would depend on the actual locations of these facilities. Moreover, because transportation routes are not currently known, and because it is impossible to reliably predict who would be involved in transportation accidents, there is no reason to believe that the impacts of transportation accidents will affect minority or low-income populations disproportionately.

5.5 USE AS URANIUM METAL

The use as metal alternative considers the use of 100% of the depleted UF_6 inventory. The use as uranium metal alternative would be very similar to the use as oxide alternative, except under the metal alternative, the depleted UF_6 would be converted to uranium metal, which was assumed to be used in the manufacture of casks for storing spent nuclear fuel or HLW. The uranium metal would serve as radiation shielding. The casks would be transported to a user facility, such as a commercial nuclear power plant or DOE facility, where they would be used to store spent nuclear fuel or HLW. Issues associated with the management of depleted uranium after use are discussed in Section 5.9.

The following is a summary of the activities analyzed under the use as uranium metal alternative:

- ***Continued Cylinder Storage (at Paducah, Portsmouth, and K-25).*** Depleted UF_6 cylinder storage would continue at each of the three current storage sites through 2028. The entire inventory would be stored at the sites through 2008, but the site inventory would decrease from 2009 through 2028 as cylinders were shipped to an independent conversion facility. The cylinder management activities that would occur at the sites were assumed to be similar to the no action alternative.

- ***Preparation of Cylinders for Shipment (at Paducah, Portsmouth, and K-25).*** Two cylinder preparation options were considered for cylinders not meeting transportation requirements: (1) a cylinder overcontainer option and (2) a cylinder transfer option (see Appendix E). The cylinder overcontainer option would not require the construction of any new facilities; for the cylinder transfer option, it was assumed that a transfer facility would be constructed at each of the three sites.

- ***Conversion (Representative Site).*** Conversion of UF_6 to uranium metal was assumed to occur from 2009 through 2028 at a newly constructed, stand-alone conversion facility.[3] As described in Appendix F, two representative conversion technologies were assessed for conversion to uranium metal. The principal product of conversion would be either HF, which would be shipped to a user facility, or CaF_2, which could be shipped for use or disposal. In

[3] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

addition, conversion to metal would also potentially produce MgF_2, which would be disposed of as nonhazardous, nonradioactive waste or LLW.

- ***Transportation (Representative Routes).*** For assessment purposes, it was assumed that all UF_6 cylinders would be transported by either truck or rail from the Paducah, Portsmouth, and K-25 sites to an independent conversion site. Following conversion, the uranium metal produced would be transported by truck or rail to a manufacturing site. In addition, MgF_2 and either HF or CaF_2 would require transportation to either a user or disposal facility. The casks would be transported by rail from the manufacturing facility to a user site.

- ***Manufacture and Use (Representative Site).*** The manufacture of uranium-metal-shielded casks was assumed to take place at a stand-alone facility dedicated to the cask manufacturing process (see Appendix H). Casks would be fabricated and sent to a user facility, such as a nuclear power plant or DOE facility, where they would be used to store spent nuclear fuel. Manufacturing was assumed to occur concurrently with conversion (i.e., from 2009 through 2028). Preparation of manufacturing facilities would occur between 1999 and 2008 (with actual construction requiring 7 years).

The potential environmental consequences of all of the activities under the use as metal alternative, as outlined above, are discussed in Sections 5.5.1 through 5.5.11.

5.5.1 Human Health and Safety

During implementation of the use as metal alternative, potential impacts to human health and safety could result from facility operations during both routine conditions and accidents. The principal facilities involved include the current storage sites, a conversion facility, and a cask manufacturing facility. These impacts are discussed in Sections 5.5.1.1 and 5.5.1.2.

5.5.1.1 Normal Facility Operations

5.5.1.1.1 Workers

The total radiation exposure of involved workers under the use as uranium metal alternative would be greater than under the no action alternative because of the additional activities required for preparation of cylinders for shipment, conversion operations, and manufacture of metal-shielded casks for use. At the three current storage sites, involved workers would be exposed to low-level radiation during routine cylinder monitoring and maintenance, cylinder relocation and painting, cylinder patching or repairing, and preparation of cylinders for shipment. Involved workers at a metal conversion facility would be exposed to radiation while handling incoming cylinders, during conversion operations, and while handling uranium metal. At a cask manufacturing facility, involved workers would be exposed to radiation during the manufacture of casks. At all facilities, radiation exposure of workers would be maintained in accordance with ALARA practices.

The number of potential radiation-induced latent cancer fatalities among involved workers from 1999 through 2039 was estimated to range from about 1 to 2, compared with 1 for the no action alternative. In addition to about 60 cylinder yard workers, from 390 to 690 involved workers would be required for the use as metal alternative (the exact number would depend on the cylinder preparation and conversion options selected). Impacts to noninvolved workers would be negligible compared to those for involved workers (i.e., less than 1% of the involved worker impacts).

Impacts to involved and noninvolved workers from exposure to chemicals during normal operations would not be expected. The workplace would be monitored to ensure that airborne chemical concentrations were within applicable health standards that are protective of human health and safety. If planned work activities were likely to expose involved workers to chemicals, they would be provided with appropriate protective equipment as necessary. The potential chemical exposure of noninvolved workers from any airborne releases during normal operations were estimated to be below levels expected to cause adverse effects (the estimated hazard indices were less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, and a cask manufacturing facility).

5.5.1.1.2 General Public

The potential impacts to members of the general public during normal operations for the use as metal alternative would be similar to the no action alternative — all exposures were estimated to be within applicable public health standards (40 CFR Part 61; DOE Order 5400.5). No LCFs from radiation exposures and no adverse effects from chemical exposures were estimated to occur among members of the general public near the three current storage sites, near a metal conversion facility, or near a cask manufacturing facility from depleted UF_6 management activities. At the current storage sites, potential impacts to members of the general public under the use as uranium metal alternative would be the same as described in Section 5.2.1.1.2.

At a metal conversion facility, members of the general public could potentially be exposed to small amounts of uranium and HF released to the air during normal operations. The total collective radiation dose to the general public from airborne emissions was estimated to range from about 0.3 to 8 person-rem over the operational period of the conversion facility (2009 through 2028). This range takes into account the different metal conversion options and environmental settings considered (see Appendix F). This level of exposure was estimated to most likely result in zero LCFs among members of the general public. The maximum radiation dose to an individual near a metal conversion site was estimated to be less than 0.03 mrem/yr from airborne emissions, well within the applicable health standards (see Section 5.2.1.1.2). If an individual were to receive the maximum estimated dose every year the conversion facility operated (2009 through 2028), the total dose would be about 1 mrem, and the resulting chance of dying from a radiation-induced latent cancer would be less than 1 in 1 million. No noncancer health effects from exposure to airborne uranium and HF releases would be expected — the hazard index for an individual near a conversion facility was estimated to be less than 0.0002.

At a cask manufacturing facility, the potential exposure of members of the general public to radiation or chemicals was estimated to be much less than at a conversion facility. The total radiation dose to the general public (2009 through 2028) was estimated to be about 0.7 person-rem, resulting in zero LCFs. The maximum radiation dose to an individual near a manufacturing site was estimated to be less than 0.002 mrem/yr from airborne emissions, well within applicable health standards (see Section 5.2.1.1.2). No noncancer health effects from chemical exposures would be expected — the hazard index for an individual near a manufacturing facility was estimated to be less than 0.00001.

5.5.1.2 Facility Accidents

5.5.1.2.1 Physical Hazards (On-the-Job Injuries and Fatalities)

Accidents occur in all work environments. In 1994, about 5,000 work-related and 3.5 million work-related injuries were reported in the United States (National Safety Council 1995). Although all work activities would be conducted in as safe a manner as possible, there is a chance that workers could be accidentally killed or injured during the use as metal alternative, unrelated to any radiation or chemical exposures.

The number of accidental worker injuries and fatalities that might occur from 1999 through 2039 were estimated on the basis of the number of workers required over this period and the historical accident fatality and injury rates in similar types of industries. The estimated number of worker fatalities and injuries would be greater than under the no action alternative because of the additional construction and operational activities required for cylinder preparation, conversion, and cask manufacturing facilities. The number of fatalities and injuries would depend on the specific cylinder preparation and conversion options.

The number of accidental fatalities and injuries would be similar to the use as oxide alternative; a total of 2 to 3 accidental worker fatalities were estimated over the 41-year period. Approximately 1,300 to 2,100 injuries (defined as injuries resulting in lost workdays) were estimated from construction and operation of facilities over the same period. At the current storage sites, the maximum total number of injuries was estimated to be about 700, assuming that a cylinder transfer facility would be constructed and operated at each site. If cylinder overcontainers were used as the cylinder preparation option, a maximum of about 150 worker injuries were estimated at the three sites combined. Approximately 660 worker injuries were estimated to occur at a conversion facility (including treatment of empty cylinders), and approximately 670 worker injuries were estimated to occur at a cask manufacturing facility. These rates would not be unique to the activities required for the alternative, but would be typical of any industrial project of similar size and scope.

5.5.1.2.2 Accidents Involving Releases of Radiation or Chemicals

Under the use as metal alternative, accidents potentially releasing radiation and chemicals could occur at the three current storage sites (during continued cylinder storage through 2028), at a metal conversion site, and at a cask manufacturing site. For each site, a range of accidents was evaluated, from those considered reasonably likely to occur (once or more in 100 years on average) to those that would be extremely rare (expected to occur less than once in 1 million years on average). The accidents considered are described in Appendix D, Section D.2.2, for continued cylinder storage; Appendix F, Section F.3.2, for conversion; and Appendix H, Section H.3.2, for cask manufacturing.

The potential consequences of cylinder accidents at the current storage sites and accidents at an oxide conversion facility are discussed in Section 5.1.1.2.2 for the no action alternative and in Section 5.3.1.2.2 for the long-term storage as oxide alternative. For the use as metal alternative, UF_6 would be converted to uranium metal rather than uranium oxide. However, the types and consequences of accidents at a metal conversion facility would be generally similar to those at an oxide conversion facility (see Appendix F, Section F.3.2). Differences between oxide conversion and metal conversion accident consequences are highlighted below.

For conversion to metal, the most severe chemical accidents would be the same as described for conversion to oxide: rupture of either an ammonia tank or an HF tank. The potential consequences of these low-probability accidents are described in Section 5.3.1.2.2. Among the accidents considered likely to occur at each facility, metal conversion accidents were estimated to have slightly lower chemical consequences to workers compared with oxide conversion accidents. At most, 5 noninvolved workers were estimated to experience potential irreversible adverse effects from likely metal conversion accidents, compared with 40 during conversion to oxide, with no noninvolved worker fatalities (this difference results because conversion to metal would not involve a potential ammonia stripper accident). For both conversion to oxide and metal, members of the general public would not be expected to experience adverse effects from likely accidents because off-site concentrations of released materials were estimated to be below levels expected to cause such effects. Injuries and fatalities among involved workers are possible for all accidents (see Section 4.3.1).

For the metal conversion accidents considered likely to occur, the consequences from radiation exposures would be the same as those described in Section 5.3.1.2.2. However, the radiological consequences of the most severe (low-probability) metal conversion accidents were estimated to be much less than those described for conversion to oxide accidents in Section 5.3.1.2.2.

Much of the difference in predicted consequences between accidents involving U_3O_8 and accidents involving uranium metal is associated with the form of the material. U_3O_8 is an easily dispersed powder, whereas on uranium metal billets, only the oxide coating can be readily dispersed. Therefore, the assumed release amounts for some of the accidents at metal conversion facilities are considerably lower than those assumed for oxide conversion facilities. At a metal conversion facility, the accident estimated to have the highest consequences from radiation exposures would be a fire involving three UF_6 cylinders, which is considered extremely unlikely (estimated to occur between once in 10,000 years and once in 1 million years). If this accident occurred, the radiation dose to a maximally exposed member of the general public was estimated to be about 15 mrem (compared with 270 mrem for the highest-consequence oxide conversion accident), resulting in an increased risk of death from cancer of about 7 in 1 million. The total population dose to the general public within 50 miles (80 km) was estimated to be 56 person-rem, resulting in zero LCFs. Among noninvolved workers, the dose to an MEI was estimated to be about 20 mrem (compared with 9,000 mrem for oxide conversion), resulting in an increased risk of death from cancer of about 8 in 1 million. The total dose to all noninvolved workers was estimated to be about 8 person-rem, resulting in zero LCFs.

At a uranium metal cask manufacturing facility, the potential consequences of the accidents considered were estimated to be less than those for potential conversion or cylinder accidents (see Appendix H). For all likely accidents, chemical concentrations were estimated to be below levels that would cause adverse effects among workers and members of the general public. In addition, the chance of a radiation-induced cancer fatality among noninvolved workers and members of the general public was estimated to be much less than 1 in 1 million if a likely accident occurred.

The metal cask manufacturing facility accident estimated to have the highest potential consequences was an accident involving the failure of a uranium metal furnace caused by an earthquake. Such an accident is considered incredible, occurring less than once in 1 million years. If such an accident occurred, it was estimated that up to 1 member of the general public and 4 noninvolved workers could experience adverse effects from chemical exposures, with no fatalities expected. If this accident occurred, the radiation dose to a maximally exposed member of the general public was estimated to be about 7 mrem, resulting in an increased risk of death from cancer of about 4 in 1 million. The total population dose to the general public within 50 miles (80 km) was estimated to be 1.9 person-rem, resulting in zero LCFs. Among noninvolved workers, the dose to an MEI was estimated to range up to 230 mrem, resulting in an increased risk of death from cancer of about 9 in 100,000. The total dose to all noninvolved workers was estimated to be about 0.087 person-rem. (The dose to the MEI noninvolved worker was estimated to be greater than the population dose among workers because the MEI worker was assumed to be at the location of maximum possible impact, very close to the accident. The worker population distribution was assumed to be evenly distributed over a large area.) All doses would be considerably below the 25-rem dose recommended by the NRC (1994a) for assessing the adequacy of protection of public health and safety from potential accidents.

5.5.2 Transportation

The major materials assumed to be transported under the use as metal alternative are summarized in Table 5.8. The transportation activities would be very similar to those described for the use as oxide alternative in Section 5.4.2. All cylinders were assumed to be transported from the current storage sites to a conversion facility. The uranium metal would be transported from the conversion facility to a cask manufacturing facility. The transportation of process chemicals (ammonia), products of conversion (anhydrous HF and MgF_2), and waste generated during processing would also be required. The casks were assumed to be transported from the manufacturing facility to a user by rail.

The overall impacts from transportation activities were estimated to be generally similar to those described for the long-term storage as oxide (Section 5.3.2) and use as oxide alternatives (Section 5.4.2). During normal transportation operations, it was estimated that up to 1 fatality could occur among workers and members of the general public from exposure to external radiation and vehicle exhaust emissions if truck shipments were used; if rail shipments were used, 0 fatalities were estimated during normal operations. The estimated number of fatalities from traffic accidents (unrelated to the cargo) are presented in Table 5.8. If truck shipments were used, it was estimated that about 3 traffic fatalities could result. If rail shipments were used, it was estimated that about 2 traffic fatalities could result. Rail transport results in a lower number of traffic fatalities, primarily because railcars have a larger shipment capacity than trucks, resulting in fewer shipments. The actual number of fatalities would be much less if the number of shipments and shipment distances were reduced. Details are provided in Appendix J.

Transportation risks would also be associated with the potential release of radiation or chemicals during accidents. The materials of greatest concern would be anhydrous HF, ammonia, and depleted UF_6 cylinders. The consequences and risks of accidents involving releases of these materials are described in detail in Section 5.3.2. Conversion to metal would result in about one-third the number of shipments of anhydrous HF compared with conversion to oxide.

5.5.3 Air Quality

The analysis of potential impacts to air quality for the use as metal alternative considered the potential for air pollutant emissions from continued cylinder storage activities occurring through 2028, cylinder preparation activities, conversion, and manufacturing activities. For continued cylinder storage and cylinder preparation activities at the current sites, impacts would be identical to those discussed for the long-term storage as UF_6 alternative (Section 5.2.3).

At a metal conversion facility, air quality impacts would depend on the actual facility location; however, estimated concentrations of criteria pollutants for the representative settings were all estimated to be within standards. Concentrations of the criteria pollutants and HF were estimated to be less than 20% of respective standards during construction and less than 5% of respective

TABLE 5.8 Summary of the Major Materials Assumed to Be Transported, Estimated Number of Shipments, and Estimated Number of Traffic Accident Fatalities under the Use as Metal Alternative, 1999 through 2039[a]

			Approximate Total Number of Shipments[b]		Estimated Traffic Accident Fatalities[c]	
Material	Origin	Destination	Truck	Rail	Truck	Rail
UF_6 cylinders	Current storage sites	Conversion site	46,422	11,600[d]	2	1
Uranium metal	Conversion site	Manufacturing site	20,840 – 21,500	7,360 – 7,520	1	0
Ammonia	Supplier	Conversion site	–	920	0	0
Anhydrous HF	Conversion site	User	–	1,640	0	0
MgF_2	Conversion site	Disposal site	10,320 – 10,780	3,800 – 3,980	0	0
LLW/LLMW	Current storage/ conversion/manu-facturing sites	Treatment/disposal site	2,460 – 6,060	–	0	0
Casks	Manufacturing site	User	–	9,060	0	0

a All materials were assumed to be transported to provide a conservative estimate of transportation impacts. A hyphen (–) denotes mode not considered for that material. Colocation of facilities would reduce transportation requirements.

b Estimated number of shipments assuming that either the truck or rail mode was used.

c Number of estimated traffic accident fatalities assuming each shipment traveled 620 miles (1,000 km) and using national average accident statistics. Estimates have been rounded to the nearest whole number.

d Number of railcars, each containing four cylinders.

standards during operations. A metal conversion facility would emit between about 4 and 11 lb/yr (1.8 and 5 kg/yr) of uranium as either U_3O_8 or UF_4. No air quality standards exist for uranium compounds; however, potential impacts of these emissions were evaluated in Section 5.5.1.1.

At a metal cask manufacturing facility, impacts on criteria pollutant emissions from construction and operation would be identical to those discussed for the use of uranium oxide alternative (Section 5.4.3). The metal cask manufacturing facility would emit 0.1 lb/yr (0.05 kg/yr) of uranium as U_3O_8. No air quality standards exist for uranium compounds; however, the potential impacts of these emissions were evaluated in Section 5.5.1.1.

5.5.4 Water and Soil

Water use from continued cylinder storage and cylinder preparation activities at the three current storage sites would be the same as discussed in Section 5.2.4. At a metal conversion facility, water use during construction (duration of about 4 years) would be between 10 and 12 million gal/yr; maximum water use during operations would be about 55 million gal/yr. Wastewater generation would range from about 25 to 30 million gal/yr. At a cask manufacturing facility, water use during construction (duration of about 7 years) would be 43 million gal/yr, and water use during operations would be about 7 million gal/yr. Wastewater generation would range from about 5 million gal/yr during operations to 9 million gal/yr during construction.

5.5.4.1 Surface Water

Under the use as metal alternative, potential impacts on surface water at the current storage sites during continued cylinder storage and cylinder preparation would be the same as discussed for storage as UF_6 (Section 5.2.4.1). At a metal conversion facility, impacts to surface water would depend on the actual location of the facility. However, based on the assessment for the representative settings considered in the PEIS, impacts to runoff and floodplain encroachment would be negligible. Concentrations of uranium in effluents from a conversion facility would range from about 25 to 53 μg/L. After dilution in nearby surface water, concentrations would be much less than the guideline of 20 μg/L.

At a cask manufacturing facility, water use and wastewater generation during operations would be less than half that required for a conversion facility. Impacts to surface water would depend on the actual location of the facility.

5.5.4.2 Groundwater

Potential impacts on groundwater quality from continued cylinder storage through 2028 and cylinder preparation activities at the current storage sites are discussed in Section 5.2.4.2. For conversion to metal and for cask manufacturing, the impacts on groundwater would depend on the actual locations of the facilities. However, the assessment for conversion to metal at representative settings indicated that impacts on recharge, depth to groundwater, or direction of flow would probably be negligible (the maximum increase over current groundwater use at the representative settings was estimated to be 0.8%). Impacts to these parameters for the manufacturing facility would depend on the size of the site in comparison with the facility, on the proximity of the site to a river with relatively large flow volume (i.e., large in comparison with annual water use and wastewater discharge), and on whether the manufacturing facility water would be drawn from a surface water source or from groundwater. Because discharges to groundwater are not planned for either conversion or manufacturing facilities (effluents would be released to nearby surface waters), direct impacts to groundwater quality would be unlikely. Good engineering and construction practices would be followed to minimize the potential for adverse impacts on groundwater resources during construction.

5.5.4.3 Soil

Potential impacts on soil at the current storage sites would be the same as discussed in Section 5.2.4.3. Potential impacts on soil at conversion to metal and manufacturing facilities would depend on their actual locations. Depending on the location of facilities and the amount of land area available, construction activities could cause changes in site topography, permeability, erosion potential, and soil quality. However, mitigative measures (e.g., contouring and reseeding excavated material, construction of retention basins, and prompt cleanup of chemical spills) would result in the impacts to soil being negligible.

5.5.5 Socioeconomics

Potential socioeconomic impacts associated with continued cylinder storage through 2028 and with cylinder preparation activities at the current storage sites are discussed in Section 5.2). The potential socioeconomic impacts of construction and operational activities of a metal conversion facility (including impacts from cylinder treatment) would depend on the facility location. Construction activities would create short-term employment (480 to 540 direct jobs and 760 to 1,100 total jobs in the peak construction year); operational activities would create between 340 and 500 direct jobs and between 780 and 1,200 total jobs per year. Direct and total income in the peak construction year would range from $17 to $21 million and from $20 to $31 million, respectively. During operations, direct and total income would range from $20 to $28 million and from $28 to $41 million per year, respectively. Employment and income totals given include estimates for a cylinder treatment facility.

For the representative settings used for analysis, the employment and income created from conversion to metal would represent a change of less than 0.1% of projected growth in these indicators of overall regional activity. The in-migration expected into the region of a metal conversion facility would have only a low impact on regional population growth rates. A moderate impact to housing could occur, with about 22% of the projected number of vacant rental housing units in the representative ROIs being required. Low impacts on local public finances would be expected; with all increases over forecasted baseline revenues and expenditures being less than 1%.

The potential socioeconomic impacts of construction and operation of a metal cask manufacturing facility would depend on facility location. Construction would create 190 direct jobs and $9 million in direct income during the peak year of construction. Operation of the facility would create 470 direct jobs and produce $33 million in direct income in each year of facility operations.

5.5.6 Ecology

The potential ecological impacts of continued cylinder storage and cylinder preparation at the three current storage sites are discussed in Section 5.2.6. Depending on the types of facilities, construction would disturb about 30 to 35 acres (12 to 14 ha) for a metal conversion facility and 90 acres (36 ha) for a manufacturing facility. Existing vegetation at the conversion and manufacturing sites would be destroyed during land-clearing activities. In addition, wildlife would be disturbed by land clearing, noise, and human presence. The extent of the impacts on ecological resources would depend on the locations of the facilities; in general, losses of 35 and 90 acres would constitute potential moderate adverse impacts in terms of habitat loss. Impacts to wetlands and state and federally protected species due to facility construction would also depend on the facility locations. Avoidance of wetland areas would be included during facility planning, and site-specific surveys for protected species would be conducted prior to finalization of facility siting plans.

Facility and transportation accidents could result in adverse impacts to ecological resources (see Sections 5.5.1 and 5.5.2). The affected species and degree of impact would depend on a number of factors such as location of accident, season, and meteorological conditions.

5.5.7 Waste Management

The waste management impacts of continued cylinder storage and cylinder preparation at the current storage sites are discussed in Section 5.2.7. During construction of the metal conversion facility, a maximum of approximately 180 m^3/yr of hazardous waste would be generated. During operations, about 190 to 1,900 m^3/yr of LLW, 1 m^3/yr of LLMW, and 7 to 10 m^3/yr of hazardous waste would be generated (ranges are the result of assessing different conversion technologies). Operation of the metal conversion facility would generate up to about 6,800 m^3/yr of nonradioactive, nonhazardous solid waste; about 90% of this would be MgF_2 produced in the conversion process. Nonradioactive, nonhazardous solid waste generation rates for conversion could exceed the current rates at the representative settings considered in the analysis, but the actual facilities would be designed to meet appropriate waste treatment demands. A cylinder treatment facility would also be required for the emptied cylinders; impacts of such a facility are discussed in Section 5.3.7.

It is possible that the MgF_2 waste generated would be sufficiently contaminated with uranium to require disposal as LLW rather than as nonradioactive, nonhazardous solid waste. The uranium level in the MgF_2 is estimated to be about 90 ppm (LLNL 1997a). Disposal as LLW might require the MgF_2 waste to be grouted, generating up to 12,300 m^3/yr of LLW for disposal. This volume would represent less than 6% of the projected DOE complexwide LLW disposal volume, constituting a low impact with respect to DOE complexwide LLW management if the LLW were considered to be DOE waste. For the metal conversion option, neutralization of HF to produce CaF_2 could result in approximately 3,500 m^3/yr of CaF_2. It is currently unknown if the CaF_2 would be sold, disposed of as nonradioactive, nonhazardous solid waste, or disposed of as LLW. If disposed of as

DOE LLW, the CaF_2 would constitute approximately 3% of the projected DOE complexwide LLW disposal volume.

The operation of a metal manufacturing facility would generate about 650 m^3/yr of LLW, 320 m^3/yr of hazardous waste, and 300 metric tons/yr of nonhazardous waste; an additional 80 m^3 of hazardous waste and 70,000 m^3 of nonradioactive, nonhazardous waste would be generated during construction. The LLW generated would be about 0.3% of the projected annual treatment volume for all DOE facilities nationwide.

5.5.8 Resource Requirements

Resource requirements for continued cylinder storage and cylinder preparation activities at the current storage sites are discussed in Section 5.2.8. Construction and operation of facilities under the use as metal alternative would consume electricity, fuel, concrete, steel and other metals, and miscellaneous chemicals that are generally irretrievable resources. The total quantity of commonly used materials is not expected to be significant and would not affect local, regional, or national availability of these materials. Some specialty materials (i.e., up to 100 tons of Monel, 4 tons of Inconel, and 10 tons of titanium) would be required for construction of conversion facilities; specialty materials would not be required for construction of manufacturing facilities. In general, facility operational requirements are not resource intensive and the resources required are not considered rare or unique.

5.5.9 Land Use

Land-use impacts from continued cylinder storage and cylinder preparation activities at the current storage sites are discussed in Section 5.2.9. Impacts on land use for conversion and manufacture would depend on the locations of these facilities. The amount of land required would range from about 30 to 35 acres (12 to 14 ha) for a conversion facility and 90 acres (36 ha) for a manufacturing facility, constituting potential moderate land use impacts. A protective action distance for emergency planning would need to be established around a metal conversion facility. This protective action distance would incorporate an area of about 960 acres (384 ha) around the facility. The potential for such impacts would be evaluated in the Phase II studies and NEPA reviews. Impacts to land use outside the boundaries of facilities would consist of potential temporary traffic impacts associated with project construction.

5.5.10 Cultural Resources

Potential impacts to cultural resources from continued cylinder storage and cylinder preparation activities at the current storage sites are discussed in Section 5.2.10. The impacts to cultural resources for metal conversion and manufacturing facilities would depend on specific locations of the facilities. Impacts to cultural resources would be evaluated in Phase II studies and avoided if necessary and appropriate.

5.5.11 Environmental Justice

Potential environmental justice issues related to continued cylinder storage and cylinder preparation activities at the current storage sites would be the same as discussed in Section 5.2.11 for the long-term storage as UF_6 alternative. Potential environmental justice impacts to minority and low-income populations from the construction and operation of metal conversion and manufacturing facilities would depend on the locations of these facilities. Moreover, because transportation routes are not currently known, and because it is impossible to reliably predict who would be involved in transportation accidents, there is no reason to believe that the impacts of transportation accidents will affect minority or low-income populations disproportionately.

5.6 DISPOSAL AS URANIUM OXIDE

Under the disposal as uranium oxide alternative, depleted UF_6 would be chemically converted to a more stable oxide form and disposed of belowground as LLW. Prior to disposal, conversion of depleted UF_6 to an oxide was assumed to take place at a newly constructed, stand-alone facility dedicated to the conversion process. Potential disposal impacts were evaluated for two different uranium oxides, U_3O_8 and UO_2 (similar to the long-term storage as oxide alternative). Both oxide forms have low-solubility in water and are relatively stable over a wide range of environmental conditions (see Appendix A). For each form, several disposal options were considered, including disposal in shallow earthen structures, belowground vaults, and an underground mine. To provide a conservative estimate of potential impacts, the conversion and disposal facilities were assumed to be located at sites other than the three current cylinder storage sites. Thus, transportation of cylinders from the three current storage sites to a conversion facility, and transportation of uranium oxide from the conversion facility to a disposal facility, was assumed.

Two physical waste forms were considered in the PEIS, ungrouted and grouted uranium oxide. Ungrouted waste refers to U_3O_8 or UO_2 in the powder or pellet form produced during the conversion process. This bulk material would be disposed of in either 55-gal (208-L) drums for U_3O_8 or 30-gal (110-L) drums for UO_2. Grouted waste refers to the solid material obtained by mixing the uranium oxide with cement and repackaging it in drums. Grouting is intended to increase structural strength and stability of the waste and to reduce the solubility of the waste in water. However, because cement is added to the uranium oxide, grouting would increase the total volume requiring disposal. Grouting of waste was assumed to occur at the disposal facility.

The potential impacts from disposal were estimated for two phases: (1) the operational phase, which includes the construction and operation of facilities and is the period during which drums would be actively placed into disposal units, and (2) the post-closure phase, which extends up to 1,000 years in the future after the assumed failure of the disposal units. No matter how well designed, all disposal facilities would be expected to release material to the environment (or "fail") eventually. In general, shallow earthen structures would be expected to contain waste material for at least several hundred years before failure, and vaults and mines would be expected to last even longer. For purposes of analysis in this PEIS, failure of all three types of disposal facilities was assumed to occur at the end of a period of institutional control, 100 years after closure. Because of the infiltration of water, uranium could ultimately migrate through the soil and eventually contaminate the groundwater. The potential impacts during the post-closure phase would result from using contaminated groundwater that could affect members of the general public.

The estimated impacts associated with the disposal alternative are subject to a great deal of uncertainty — especially during the post-closure phase. In general, the degree of uncertainty associated with potential post-closure impacts is greater than that for the other impacts considered in the PEIS. The analysis of post-closure impacts considered an extremely long period of time and was based on predicting the behavior of the uranium material after disposal 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 included such factors as soil characteristics, water infiltration rates, depth to the underlying groundwater table, chemistry of different uranium compounds in the soil, and locations of future human receptors. These factors could vary widely, depending on site-specific conditions. In response, the assumptions used in the PEIS were generally selected in a manner intended to produce conservative estimates of impacts, that is, the assumptions tend to overestimate the potential impacts.

The following is a summary of the activities analyzed for the disposal as uranium oxide alternative:

- ***Continued Cylinder Storage (at Paducah, Portsmouth, and K-25).*** Depleted UF_6 cylinder storage would continue at each of the three current storage sites through 2028. The entire inventory would be stored at the sites through 2008, but the site inventory would decrease from 2009 through 2028 as cylinders were shipped off-site to an independent conversion facility. The cylinder management activities that were assumed to occur at the sites would be similar to the no action alternative.

- ***Preparation of Cylinders for Shipment (at Paducah, Portsmouth, and K-25).*** Two cylinder preparation options for cylinders not meeting transportation requirements were considered: (1) a cylinder overcontainer option and (2) a cylinder transfer option. The cylinder overcontainer option would not require the construction of any new facilities; for the cylinder transfer option, it was assumed that a transfer facility would be constructed at each of the three current storage sites.

- ***Conversion (Representative Site).*** Conversion was assumed to occur from 2009 through 2028 at a newly constructed, stand-alone conversion facility.[4] As described in Appendix F, two representative conversion technologies were assessed for conversion to U_3O_8, and three for conversion to UO_2. The principal product of conversion would be either anhydrous HF, which would be shipped to a user facility, or CaF_2, which could be shipped for use or disposal.

- ***Transportation (Representative Routes).*** All UF_6 cylinders were assumed to be transported by either truck or rail from the Paducah, Portsmouth, and K-25 sites to an independent conversion site. Following conversion, the U_3O_8 or UO_2 produced was assumed to be transported in drums by truck or rail to a disposal facility. In addition, HF and CaF_2 would require transportation to either a user or disposal facility.

- ***Disposal (Generic Site).*** Three options were considered for the disposal of oxide, including disposal in shallow earthen structures, vaults, or a mine (see Appendix G). Drums of oxide would be received and disposed of at the disposal facility from 2009 through 2028. Construction of the disposal units would continue over a 20-year period while the drums were being received. Grouting would also occur at the disposal facility, if necessary.

The potential environmental consequences of all of the activities under the disposal as uranium oxide alternative, as outlined above, are provided in Sections 5.6.1 through 5.6.11.

5.6.1 Human Health and Safety

During implementation of the disposal as oxide alternative, potential impacts to human health and safety could result from facility operations during both routine conditions and accidents. The principal facilities involved include the current storage sites, a conversion facility, and a disposal facility. These impacts are discussed in Sections 5.6.1.1 and 5.6.1.2.

5.6.1.1 Normal Facility Operations

5.6.1.1.1 Workers

The total radiation exposure of involved workers under the disposal as oxide alternative would be greater than under the no action alternative because of the additional activities required for

[4] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

preparation of cylinders for shipment, conversion operations, and disposal operations. Impacts to workers would only occur during the operational phase of disposal.

At the three current storage sites, involved workers would be exposed to low-level radiation during routine cylinder monitoring and maintenance, cylinder relocation and painting, cylinder patching or repairing, and preparation of cylinders for shipment. Involved workers at a conversion facility would be exposed to radiation while handling incoming cylinders, during conversion operations, and while handling uranium oxide. At a disposal facility, involved workers would be exposed to radiation during the placement of drums of uranium oxide into the disposal areas or during the grouting of waste. At all facilities, radiation exposure of workers would be maintained in accordance with ALARA practices.

The estimated numbers of potential radiation-induced LCFs among involved workers from 1999 through 2039 are summarized in Figure 5.4, assuming that the oxide would be grouted before disposal, and in Figure 5.5, assuming that the oxide would not be grouted. A total of about 1 to 2 additional LCFs were estimated among the involved worker population, compared with 1 LCF for the no action alternative. (The impacts to noninvolved workers were estimated to be negligible compared to involved workers.) The impacts to involved workers would be similar for the disposal of U_3O_8 and UO_2, with slightly higher doses estimated for the disposal of grouted waste compared to ungrouted waste because of the additional worker activities required by grouting. The impacts to involved workers also would be similar for disposal in shallow earthen structures, vaults, or a mine because all three options would involve handling the same amount of radioactive material and require the same general types of activities.

Impacts to involved and noninvolved workers from exposure to chemicals during normal operations would not be expected. The workplace would be monitored to ensure that airborne chemical concentrations were within applicable health standards that are protective of human health and safety. If planned work activities were likely to expose involved workers to chemicals, they would be provided with appropriate protective equipment as necessary. The potential chemical exposure of noninvolved workers from airborne releases during normal operations were estimated to be below levels expected to cause adverse effects (the estimated hazard indices were less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, and a disposal facility).

5.6.1.1.2 General Public

Potential impacts to members of the general public were estimated for the operational phase of the disposal as oxide alternative, which is the time that UF_6 would be converted to oxide and actively disposed of, and for the post-closure (long-term) phase, defined to be within 1,000 years in the future after the disposal facility was assumed to fail.

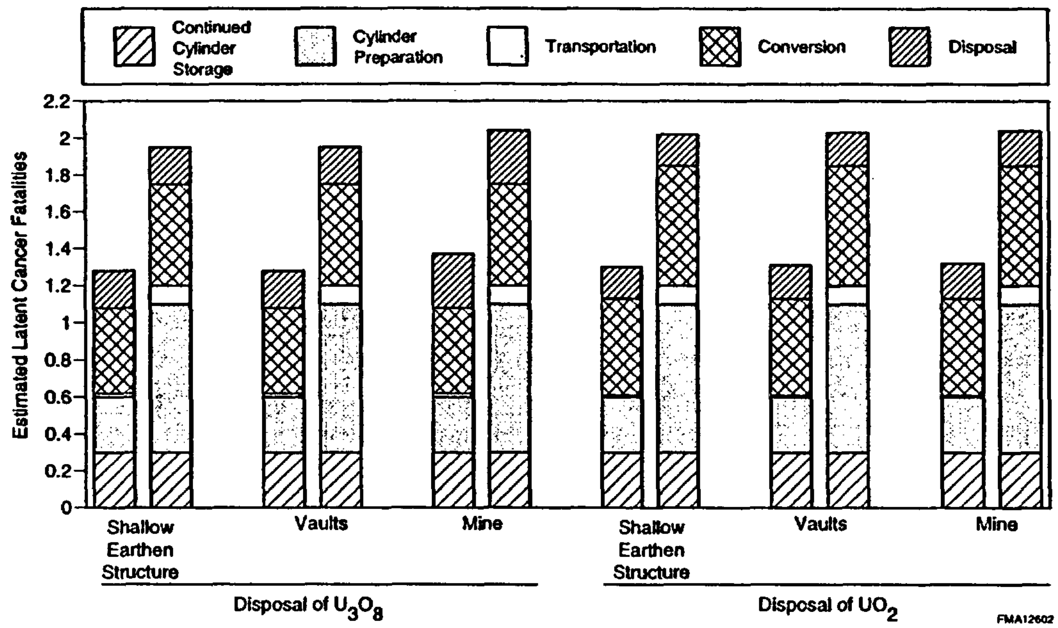

FIGURE 5.4 Total Estimated Number of LCFs among Involved Workers from Radiation Exposures during Normal Operations for the Disposal as Oxide Alternative, Assuming Grouted Waste, 1999 through 2039 (Note: The two bars presented for each option represent the minimum and maximum impacts estimated.)

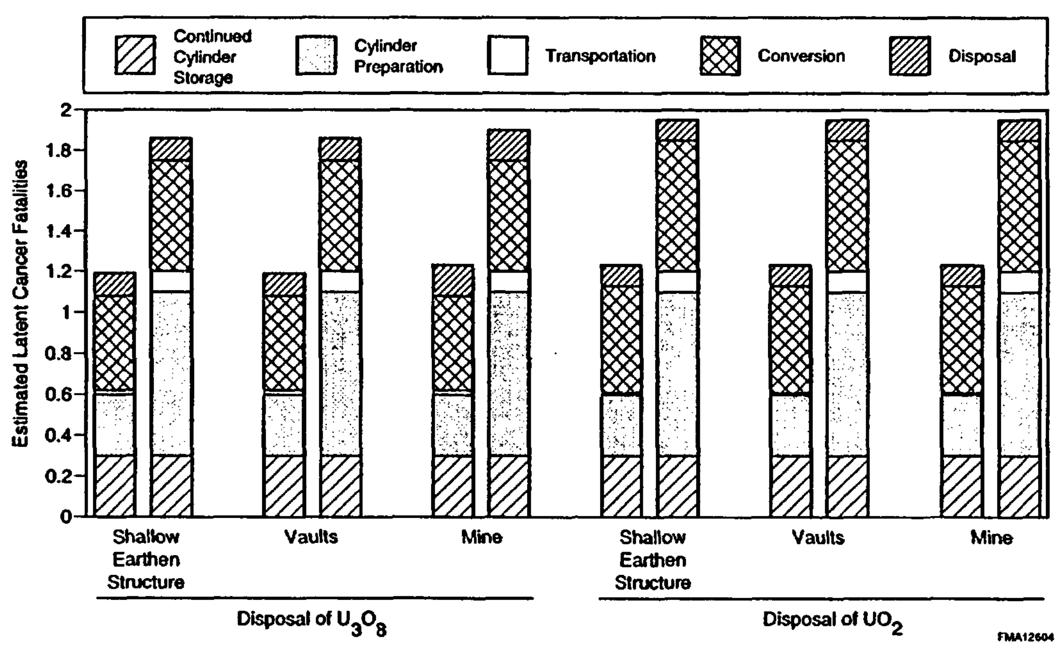

FIGURE 5.5 Total Estimated Number of LCFs among Involved Workers from Radiation Exposures during Normal Operations for the Disposal as Oxide Alternative, Assuming Ungrouted Waste, 1999 through 2039 (Note: The two bars presented for each option represent the minimum and maximum impacts estimated.)

Operational Phase. The potential impacts to members of the general public during the operational phase of the disposal as oxide alternative would be similar to the no action alternative — all exposures were estimated to be within applicable public health standards. No LCFs from radiation exposures and no adverse effects from chemical exposures were estimated to occur among members of the general public near the three current storage sites, near a conversion facility, or near a disposal facility from depleted UF_6 management activities.

At the current storage sites, potential impacts to members of the general public under the disposal as uranium oxide alternative would be exactly the same as described in Section 5.2.1.1.2 for the long-term storage as UF_6 alternative. In addition, impacts to members of the general public in the vicinity of an oxide conversion facility would be the same as those described for the long-term storage as oxide alternative in Section 5.3.1.1.2.

At a disposal facility, potential exposure of members of the general public to radiation or chemicals was estimated to be much less than at a conversion facility. During the disposal of ungrouted oxide, the drums would be disposed of without being reopened at the disposal facility; therefore, no releases would be expected during normal operations, and no off-site impacts to members of the general public would occur. Small airborne releases of uranium (through process filters) would occur if the oxide were grouted because the drums would be opened and the oxide mixed with cement prior to disposal. The total radiation dose to the general public (1999 through 2039) in the vicinity of a disposal site from airborne releases was estimated to be about 0.2 person-rem, resulting in zero LCFs. The maximum radiation dose to an individual near a disposal site was estimated to be about 0.05 mrem/yr from airborne emissions, well within applicable health standards (40 CFR Part 61; DOE Order 5400.5). No noncancer health effects from chemical exposures would be expected — the estimated hazard index for an individual near a disposal site was estimated to be less than 0.0002.

Post-Closure Phase (Long-Term Impacts). Potential impacts to members of the general public near the disposal site would be possible in the future if the groundwater became contaminated or if a person inadvertently intruded on the disposal facility. The extent of possible groundwater contamination would depend on the location and characteristics of the disposal site, such as the annual rainfall rate, the depth to the groundwater, and soil properties, as well as on the design of the disposal facility. Because of site selection and design considerations, groundwater contamination would not be expected to occur until hundreds to thousands of years after the disposal facility had been closed.

The potential effects on human health in the future were estimated by assuming that a person lived at the edge of the disposal site and used groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. In addition, it was assumed that, at some point in the future, the engineered barriers of the disposal facility would fail, allowing uranium to be released into the soil. To address uncertainties related to the disposal site properties, the facility was assumed to be located at either a dry setting (typical of the western United States) or a wet setting (typical of the eastern

United States). In addition, it was assumed that the site had soil properties that permitted uranium to either move rapidly through the soil (mobile situation) or slowly through the soil (immobile situation). The potential radiation doses from future groundwater contamination were based on the estimated groundwater concentrations discussed in Section 5.6.4.2 and Appendix I, Section I.4.

In a dry setting, the groundwater analysis indicated that measurable groundwater contamination would not occur until more than 1,000 years after failure of the disposal facility, even if the uranium were assumed to move rapidly through the soil. Groundwater contamination would not occur within 1,000 years because of the small amount of rainfall typical of a dry setting and the resulting small amount of water that would infiltrate the disposal facility. In addition, a large distance to the groundwater table would be expected in a dry environment. Therefore, no radiation or chemical exposures of members of the general public from contaminated groundwater would be expected within 1,000 years following failure of a disposal facility in a dry environment.

In a typical wet setting, groundwater contamination was estimated to occur within 1,000 years after failure of the disposal facility for shallow earthen structures, vaults, and mines. The maximum radiation dose to an individual assumed to use contaminated groundwater was estimated to be about 100 mrem/yr if the soil properties were such that the uranium moved rapidly through the soil. If the depleted uranium was classified as LLW, the radiation doses from using contaminated groundwater would exceed the dose limit of 25 mrem/yr specified in 10 CFR Part 61 and DOE Order 5820.2A. In addition, the groundwater concentrations would be great enough to cause potential adverse effects from chemical exposures. The chemical hazard indices were calculated to range up to 10, indicating the potential for chemically induced adverse effects. However, impacts from using contaminated groundwater could be reduced or eliminated by treating the water or by using an alternative source of water.

In addition to possible exposures resulting from the use of contaminated groundwater, health impacts could result if a person inadvertently intruded or if the cover material (i.e., soil) above the disposal facility eroded away. The radiation dose was estimated to be as high as 10 rem/yr for a hypothetical future resident living on the disposal site in such a case (see Appendix I, Section I.4). Chemical health effects from uranium exposure could also be possible. Erosion of the cover material would probably not occur until several thousands of years after closure of a shallow earthen structure or vault disposal facility and would probably not occur at all for a mine disposal facility. If cover materials were to erode away, radiation exposures could be easily mitigated by adding new cover material. These considerations would be addressed in more detail during disposal facility design, site selection, licensing activities, and Phase II analyses and NEPA reviews if disposal were selected as the preferred alternative.

5.6.1.2 Facility Accidents

5.6.1.2.1 Physical Hazards (On-the-Job Injuries and Fatalities)

Accidents occur in all work environments. In 1994, about 5,000 work-related fatalities and 3.5 million work-related injuries were reported in the United States (National Safety Council 1995). Although all work activities would be conducted in as safe a manner as possible, there is a chance that workers could be accidentally killed or injured during the disposal as oxide alternative, unrelated to any radiation or chemical exposures.

The number of accidental worker injuries and fatalities that might occur from 1999 through 2039 were estimated on the basis of the number of workers required over this period and the historical accident fatality and injury rates in similar types of industries. The estimated number of worker fatalities and injuries would be greater for the disposal as oxide alternative than the no action alternative because of the additional construction and operational activities required for cylinder preparation, conversion, and disposal facilities. The number of fatalities and injuries would depend on the specific cylinder preparation, conversion, and disposal options selected.

Considering all options, a range of 1 to 3 accidental worker fatalities from construction and operation of facilities were estimated over the 41-year period. The estimated number of accidental injuries (defined as injuries resulting in lost workdays) are shown in Figure 5.6. Approximately 700 to 1,800 injuries were estimated from construction and operation of facilities over the same period. At the current storage sites, the maximum total number of injuries was estimated to be about 700, assuming a cylinder transfer facility would be constructed and operated at each site. If cylinder overcontainers were used as the cylinder preparation option, a maximum of about 150 worker injuries were estimated at the three sites combined. Approximately 660 worker injuries were estimated to occur at a conversion facility (including treatment of empty cylinders), and approximately 100 to 450 worker injuries were estimated to occur at a disposal facility. These rates would not be unique to the activities required for the alternative, but would be typical of any industrial project of similar size and scope.

5.6.1.2.2 Accidents Involving Releases of Radiation or Chemicals

Under the disposal as oxide alternative, accidents potentially releasing radiation and chemicals could occur at the three current storage sites (during continued cylinder storage through 2028), at an oxide conversion site, and at a disposal site. For each site, a range of accidents was evaluated, from those considered reasonably likely to occur (once or more in 100 years on average) to those that would be extremely rare (expected to occur less than once in 1 million years on average). The accidents considered are described in Appendix D, Section D.2.2, for continued cylinder storage; Appendix F, Section F.3.2, for conversion; and Appendix I, Section I.3.2, for disposal.

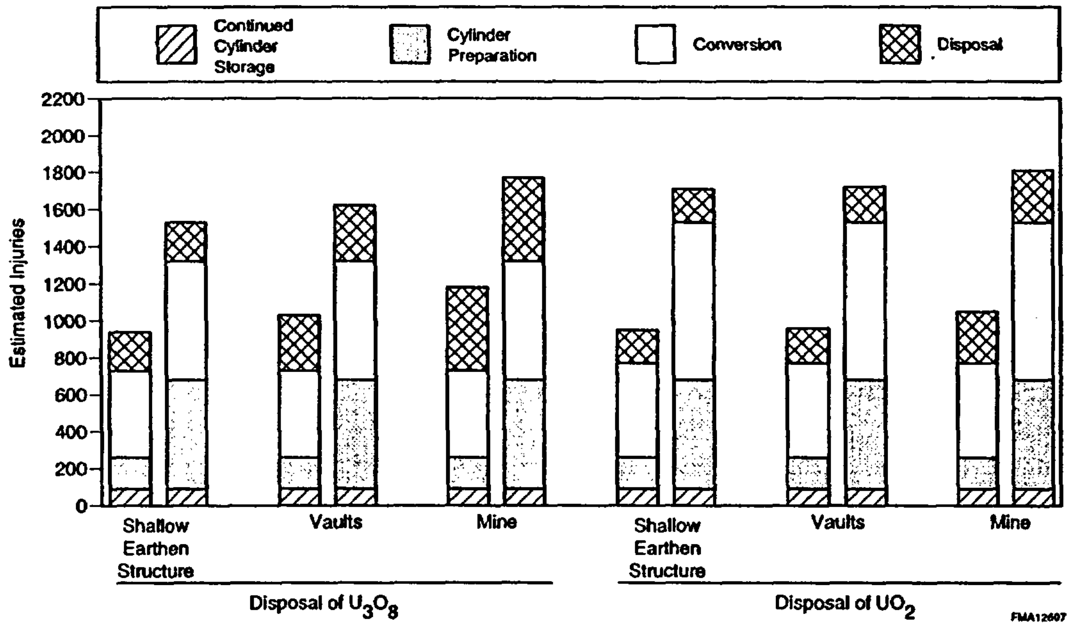

FIGURE 5.6 Total Estimated Number of On-the-Job Injuries (defined as injuries resulting in lost workdays) among All Workers from Construction and Operation of Facilities for the Disposal as Oxide Alternative, 1999 through 2039 (The two bars for each option represent the minimum and maximum impacts estimated.)

The potential consequences of cylinder accidents at the current storage sites and accidents at an oxide conversion facility are described in Section 5.1.1.2.2 for the no action alternative and in Section 5.3.1.2.2 for the long-term storage as oxide alternative. At a disposal facility, the potential consequences of all the accidents considered were estimated to be much less than potential conversion or cylinder accidents (see Appendix I). The disposal facility accident estimated to have the highest potential consequences was an earthquake accident during grouting operations that would release uranium oxide. This accident is considered unlikely. If such an accident occurred, potential chemical exposures of members of the general public were estimated to be much less than levels expected to cause adverse effects. Among noninvolved workers, up to 1 worker could experience adverse effects (mostly mild and transient effects) from chemical exposure to uranium, with no fatalities expected. This accident could also result in radiation exposures of workers and members of the general public. Among noninvolved workers, zero LCFs were estimated to be caused by radiation exposure if the accident did occur. Similarly, among members of the general public, zero radiation-induced LCFs were estimated if the accident occurred. The dose to any member of the general public was estimated to be considerably below the 25-rem dose recommended by the NRC (1994a) for assessing the adequacy of protection of public health and safety from potential accidents.

5.6.2 Transportation

The major materials assumed to be transported under the disposal as oxide alternative are summarized in Table 5.9. The transportation activities assumed to be required for the disposal as oxide alternative are the same as those described for long-term storage as oxide alternative in Section 5.3.2. The two alternatives differ only in the destination of the uranium oxide after conversion: it would either be shipped to a long-term storage facility or to a disposal facility. Because the locations of future storage or disposal sites will be evaluated in Phase II studies and NEPA reviews, in both cases the potential impacts from these shipments were estimated assuming a representative route of 620 miles (1,000 km). Therefore, the estimated impacts are the same for the two alternatives.

TABLE 5.9 Summary of the Major Materials Assumed to Be Transported, Estimated Number of Shipments, and Estimated Number of Traffic Accident Fatalities under the Disposal as Oxide Alternative, 1999 through 2039[a]

			Approximate Total Number of Shipments[b]		Estimated Traffic Accident Fatalities[c]	
Material	Origin	Destination	Truck	Rail	Truck	Rail
UF_6 cylinders	Current storage sites	Conversion site	46,422	11,600[d]	2	1
Uranium oxide (U_3O_8 or UO_2)	Conversion site	Disposal site	25,500 – 26,800	8,480 – 8,960	1	1
Ammonia	Supplier	Conversion site	520 (U_3O_8 conversion)	960 – 1,120 (UO_2 conversion)	0	0
Anhydrous HF (if produced)	Conversion site	User	–	4,860	0	0
CaF_2 (if HF neutralized)	Conversion site	User or disposal site	19,800	7,300	1	0
LLW/LLMW	Current storage/ conversion sites	Treatment/disposal site	900 – 2,360	–	0	0

[a] All materials were assumed to be transported to provide a conservative estimate of transportation impacts. A hyphen (–) denotes mode not considered for that material. Colocation of facilities would reduce transportation requirements.

[b] Estimated number of shipments assuming that either the truck or rail mode was used.

[c] Number of estimated traffic accident fatalities assuming each shipment traveled 620 miles (1,000 km) and using national average accident statistics. Estimates have been rounded to the nearest whole number.

[d] Number of railcars, each containing four cylinders.

In summary, it was assumed that cylinders would be transported from the current storage sites to an oxide conversion facility and the uranium oxide would be transported to a disposal facility (rather than a long-term storage facility). Process chemicals (ammonia), products of conversion (anhydrous HF or CaF_2), and any waste generated was also assumed to be transported. The impacts of these shipments during both normal and accident conditions are described in detail in Section 5.3.2.

5.6.3 Air Quality

The analysis of potential impacts on air quality for the disposal alternative considered the potential for air pollutant emissions from continued cylinder storage through 2028, cylinder preparation activities, conversion, and disposal activities. For continued cylinder storage and cylinder preparation activities at the current sites, impacts for the disposal as oxide alternative would be the same as those discussed for the long-term storage as UF_6 alternative (Section 5.2.3). For conversion to oxide, air quality impacts would be the same as discussed for the long-term storage as oxide alternative (Section 5.3). Air quality impacts from construction and operation of a disposal facility would depend on the actual facility location. Based on analyses for a generic setting of typical size for this type of facility, the concentrations of criteria pollutants were estimated to be within applicable standards. The criteria pollutant with the highest potential emissions would be NO_x; concentrations of NO_x were estimated to be within standards and guidelines, even when combining the effects of construction and operational activities which would be conducted simultaneously.

For disposal options that include grouting the waste, operation of a waste form facility would emit about 0.6 lb/yr (0.3 kg/yr) or 1.1 lb/yr (0.5 kg/yr) of uranium for grouted U_3O_8 and grouted UO_2 options, respectively. No air quality standards exist for uranium compounds; however, potential health impacts of these emissions were evaluated in Section 5.3.1.1.

5.6.4 Water and Soil

Water use for continued cylinder storage and cylinder preparation activities at the current storage sites would be the same as discussed in Section 5.2.4. At a conversion facility, water use would be the same as discussed in Section 5.3.4. For disposal, construction and operations would be occurring concurrently over the 20-year disposal period. Water use for construction would range from 0.2 to 2.8 million gal/yr; water use for operations would range from 0.1 to 20 million gal/yr. The upper ends of the ranges correspond to options for disposing of grouted wasteforms because the grouting operations would require larger amounts of water. Wastewater generation would range from about 0.1 to 0.2 million gal/yr for construction and from 0.1 to 1.3 million gal/yr for operations.

5.6.4.1 Surface Water

Under the disposal alternative, potential impacts on surface water at the current storage sites during continued storage of the cylinders and cylinder preparation would be the same as discussed for storage as UF_6 (Section 5.2.4.1). At a conversion facility, potential impacts to surface water would be the same as discussed for the long-term storage as oxide alternative (Section 5.3.4.1). At a disposal site, water use and wastewater generation would be approximately half or less than that required for a conversion facility. Impacts to surface water would depend on the actual location of the facility.

5.6.4.2 Groundwater

5.6.4.2.1 Operational Phase

Potential impacts on groundwater quality at the current storage sites from continued cylinder storage and cylinder preparation activities would be the same as discussed in Section 5.2.4.2. At a conversion facility, the potential impacts would be the same as discussed in Section 5.3.4.2. Potential groundwater impacts at a disposal facility would depend on the size of the site in comparison with the facility, on the proximity of the site to a river with fairly large flow volume (i.e., large in comparison with annual water use and wastewater discharge), and on whether the disposal facility water would be drawn from a surface water source or from groundwater. Because discharges to groundwater are not planned for these facilities, there would be no direct impacts on groundwater quality. Good engineering and construction practices would be followed to minimize the potential for adverse impacts during construction.

5.6.4.2.2 Post-Closure Phase (Long-Term Impacts)

For disposal, impacts on groundwater in the distant future would depend on the location of the facility. If the disposal facility were located in a dry environment typical of the western United States, groundwater impacts in the form of elevated uranium concentrations (i.e., concentrations greater than the proposed drinking water standard of 20 μg/L) would not occur for at least 1,000 years after failure of the facility. However, for a disposal facility in a wet environment, typical of the eastern United States, groundwater quality could be affected by contamination migrating from the disposal facility within 1,000 years after failure of the engineered barriers.

For purposes of analysis, if no sustained effort was made to maintain a disposal facility, failure of the facility (defined as the release of uranium material to the surrounding soil) was assumed to occur 100 years after closure (see Appendix I). This failure could be caused by natural degradation of the disposal structures over time, primarily from physical processes such as the intrusion of water. With good engineering, disposal facilities would actually be unlikely to fail for several hundred years or more.

Following failure, the release of uranium from the facility would occur very slowly as water moved through the disposed material. The amount of groundwater contamination, as well as the length of time it would take for the groundwater to become contaminated, would depend on the integrity of the drums and the engineered barriers, whether or not the waste was grouted, and site-specific properties of the soil surrounding the disposal facility. Without more precise information concerning the expected duration of effectiveness for the containers and engineered barriers in the specific disposal facility environment, as well as site-specific soil and hydrological properties, the potential groundwater concentrations are subject to a large degree of uncertainty.

For a generic wet setting, if the soil properties were such that the uranium moved relatively rapidly through the soil, the uranium concentration in the groundwater beneath the facility 1,000 years after facility failure was estimated to range from about 230 to 425 pCi/L (910 to 1,700 μg/L) for disposal of U_3O_8 and from about 190 to 320 pCi/L (760 to 1,300 μg/L) for disposal of UO_2. These uranium concentrations would exceed the guideline of 20 μg/L used for comparison. If the uranium moved less rapidly through the soil surrounding the disposal facility, uranium concentrations in the groundwater beneath the facility after 1,000 years could be much less than the guideline value. However, the concentrations would increase with time, ultimately approaching the concentrations discussed for the mobile situation, and exceeding the guideline.

For both U_3O_8 and UO_2, larger groundwater concentrations were estimated over the long term for disposal of grouted waste compared with ungrouted waste because grouting would increase the waste volume, essentially exposing a larger cross section of material to infiltrating water. However, further studies using site-specific soil characteristics would be necessary to determine the effect of grouting on long-term waste mobility. Grouting might reduce the dissolution of the waste and subsequent leaching of uranium into the groundwater in the first several hundred years after failure. However, over longer periods, the grouted form would be expected to deteriorate and, because of the long half-life of uranium, the performance of grouted and ungrouted waste would be essentially the same. Depending on soil properties, it is also possible that grouting could increase the solubility of the uranium material, resulting in more rapid groundwater contamination.

The potential impacts on groundwater would be essentially similar for disposal in shallow earthen structures, vaults, and or a mine because of the long time periods considered and the fact that the calculations were performed for 1,000 years after each facility was assumed to fail. However, shallow earthen structures would be expected to contain the waste material for a period of several hundred years before failure, and vaults and a mine would be expected to last even longer. Therefore, vault and mine disposal would provide greater protection in a wet environment. In addition, a vault or a mine would be expected to provide additional protection against erosion of the cover material (and possible exposure of the waste material) 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.

5.6.4.3 Soil

Potential impacts on soil at the current storage sites and at a conversion site would be the same as discussed in Sections 5.2.4.3 and 5.3.4.3, respectively. Impacts at a disposal facility would depend on the actual location. Potential impacts, which would tend to be temporary, would generally result from the material excavated during construction that would be left on-site. The largest potential impacts on soil would occur from excavation for disposal. Construction for disposal could require excavating from about 300,000 to 2.6 million yd^3 (230,000 to 2.0 million m^3) of consolidated material. In the short term, this amount of material would cause changes in site topography. In the long term, contouring and reseeding would return the soil to its former condition, and the impacts would be minor. If a previously existing mine were used for disposal, excavation requirements could be significantly reduced, and potential impacts on soil would be much less.

5.6.5 Socioeconomics

Potential socioeconomic impacts associated with continued cylinder storage through 2028 and with cylinder preparation activities are discussed in Section 5.2.5. Socioeconomic impacts for an oxide conversion facility are summarized in Section 5.3.5. The potential socioeconomic impacts of construction and operation of a disposal facility (including the waste form facility) would depend on the facility location, facility type (i.e., shallow earthen structure, vault, or mine), and whether grouted or ungrouted oxide was disposed of. Construction would create from 65 to 770 direct jobs and from $3.5 to $42 million in direct income during the peak year of construction. Operation of the disposal facility would create from 60 to 180 direct jobs and produce from $6 to $18 million in direct income in each year of facility operation. For disposal, construction and operations would be occurring concurrently over the 20-year disposal period.

5.6.6 Ecology

5.6.6.1 Operational Phase

Potential impacts to ecological resources from continued storage through 2028 at the current storage sites are discussed in Section 5.2.6. Depending on the types of facilities, construction would disturb about 30 to 40 acres (12 to 16 ha) for conversion, 46 to 470 acres (18 to 190 ha) for disposal as U_3O_8, and 30 to 150 acres (12 to 61 ha) for disposal as UO_2. Existing vegetation at a conversion or disposal site would be destroyed during land-clearing activities. In addition, wildlife would be disturbed by land clearing, noise, and human presence. The extent of the impacts on ecological resources would depend on the locations of the facilities; in general, losses of 40 and 470 acres would constitute potential moderate and potential large adverse impacts in terms of habitat loss, respectively. Impacts to wetlands and state and federally protected species due to facility construction would also depend on the facility locations. Avoidance of wetland areas would be included during facility planning, and site-specific surveys for protected species would be conducted prior to finalization of facility siting plans.

Facility and transportation accidents, as discussed in Sections 5.6.1 and 5.6.2, could also 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 accident, season, and meteorological conditions.

5.6.6.2 Post-Closure Phase (Long-Term Impacts)

Potential impacts to aquatic biota could occur in the future if the disposal facility were to fail. Failure of facility integrity could result in contamination of groundwater at a wet setting within 1,000 years, as described in Section 5.6.4.2. Groundwater could discharge to the surface (such as in wetland areas) near the facility, thus exposing biota to contaminants. Groundwater concentrations of uranium calculated for 1,000 years after facility failure would range up to about 425 pCi/L. Adverse impacts to aquatic biota could result from exposure to soluble uranium compounds within this concentration range, although the resulting dose rates to maximally exposed organisms would be less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d for aquatic organisms, as specified in DOE Order 5400.5. These potential ecological impacts, which correspond to the groundwater concentration estimated for 1,000 years after failure of the disposal facility, are highly uncertain and would depend on site-specific characteristics and on whether aquatic biota would actually contact contaminants.

5.6.7 Waste Management

The waste management impacts of continued cylinder storage and cylinder preparation at the current sites are discussed in Section 5.2.7; waste management impacts of conversion at representative settings are discussed in Section 5.3.7. The maximum disposal volume of material would result from the disposal of grouted U_3O_8, approximately 312,000 m^3 over the duration of the program. This amount would represent approximately 7% of the projected DOE complexwide LLW disposal volume over the same approximate period (see Appendix C, Section C.10). If the U_3O_8 were not grouted, about 150,000 m^3 would be disposed of, representing about 3.5% of the projected DOE disposal volume. The volume of UO_2 disposed of would be approximately 72,000 m^3 if grouted and

48,000 m^3 if ungrouted, representing less than 2% of the projected DOE disposal volume in either case. Although these amounts of waste would be appreciable, it is expected that disposal would have only a low impact on DOE's total LLW disposal capabilities.

5.6.8 Resource Requirements

Resource requirements for continued cylinder storage, cylinder preparation, and conversion to oxide are discussed in Section 5.3.8. Construction and operation of facilities under the disposal alternative would consume electricity, fuel, concrete, steel and other metals, and miscellaneous chemicals that are generally irretrievable resources. Specialty materials would not be required for construction of disposal facilities. In general, facility operational requirements are not resource intensive and the resources required are not considered rare or unique. However, for disposal in a mine, large quantities of electrical energy would be required during construction (up to 1,100 MW-yr) because the majority of the construction equipment required to build the underground portion would be powered by electricity. The impact of this high electrical requirement on local energy resource use would depend on the location of the facility and the existing infrastructure. If a previously existing mine were used for disposal, excavation and construction requirements would probably be reduced, depending on the characteristics and condition of the mine, and the electrical requirements would be subsequently reduced.

5.6.9 Land Use

Land-use impacts at the current cylinder storage sites from continued storage and cylinder preparation activities are discussed in Section 5.2.9. Impacts on land use for conversion and disposal would depend on the locations of the facilities. The amount of land required would range from about 30 to 40 acres (12 to 16 ha) for conversion, 46 to 470 acres (18 to 190 ha) for disposal of U_3O_8, and 30 to 150 acres (12 to 61 ha) for disposal of UO_2, constituting potential impacts to land use ranging from negligible to large. The large range for disposal results from two factors: (1) differences in the amounts of land required for shallow earthen structures, vaults, and mine disposal facilities; and (2) differences caused by whether the material is grouted (mixed with cement) or ungrouted prior to disposal. Grouting of the oxide would approximately double the amount of land required for disposal because the volume requiring disposal would increase. The smallest amount of land required for disposal would be for disposal of ungrouted UO_2 in shallow earthen structures, with the largest amount of land required for disposal of grouted U_3O_8 in a mine. For disposal in a mine, on-site topographical modifications associated with the disposition of excavated material could potentially affect future on-site land use. The potential for such impacts would be evaluated in site-specific NEPA documentation. Potential impacts to land use outside the boundaries of facilities would consist of temporary traffic impacts associated with project construction.

5.6.10 Cultural Resources

Potential impacts to cultural resources from continued cylinder storage and cylinder preparation activities at the three existing sites are discussed in Section 5.2.10. The impacts to cultural resources for conversion and disposal facilities would depend on specific locations of the facilities. Impacts to cultural resources would be evaluated in Phase II studies and avoided if necessary.

5.6.11 Environmental Justice

Potential environmental justice issues related to continued cylinder storage and cylinder preparation activities at the current storage sites would be the same as discussed in Section 5.2.11 for the long-term storage as UF_6 alternative. Potential environmental justice impacts to minority and low-income populations from the construction and operation of conversion and disposal facilities would depend on the locations of these facilities. Moreover, because transportation routes are not currently known, and because it is impossible to reliably predict who would be involved in transportation accidents, there is no reason to believe that the impacts of transportation accidents will affect minority or low-income populations disproportionately.

5.7 PREFERRED ALTERNATIVE

DOE's preferred alternative is to begin conversion of the depleted UF_6 inventory as soon as possible, either to uranium oxide, uranium metal, or a combination of both, while allowing for use of as much of this inventory as possible. The impacts of alternative strategies that would involve 100% use as oxide or 100% use as metal were analyzed and presented in Sections 5.4 and 5.5, respectively. Under the preferred alternative, conversion to oxide for use or long-term storage would begin as soon as practicable, with conversion to metal occurring only if uses are identified. The percentage of the depleted UF_6 inventory that would be used as oxide or converted and used as metal could vary. Additionally, most of the inventory would likely require interim storage as depleted uranium oxide pending use. Therefore, the impacts of the preferred alternative could involve a combination of the alternatives evaluated in the PEIS. To represent the impacts of a combination of use as oxide, use as metal, and storage as oxide, a strategy involving 25% use as oxide, 25% use as metal, and 50% long-term storage as oxide (henceforth called the combination strategy) was also analyzed and is discussed in this section. DOE has no preference regarding the actual percentages of the inventory that would be used as oxide or as metal; the 25% values used in this analysis were chosen for purposes of analysis.

In this PEIS, the use as oxide alternative assumed that UO_2 oxide would be used as radiation shielding in storage casks for spent nuclear fuel or HLW. However, current technology research and development on the use of uranium oxide as shielding material shows that the U_3O_8 oxide form could also be used, although somewhat less efficiently because of its lower density. In the analyses of potential impacts of the combination strategy presented in the following sections (Sections 5.7.1 through 5.7.11), the impacts for the conversion to oxide alternative and long-term storage as oxide alternative are therefore given as a range of impacts for either U_3O_8 or UO_2. The impacts from the manufacture and use as oxide were calculated and are presented for the UO_2 form only; these impacts are considered to be representative of impacts for manufacture and use as oxide in general.

The impacts of the combination strategy would include impacts during continued cylinder storage; preparation of cylinders for shipment; conversion of UF_6 to uranium oxide (U_3O_8 or UO_2) and metal; treatment of empty cylinders; manufacture of uranium oxide and uranium metal casks; long-term storage of uranium oxide (U_3O_8 or UO_2); and transportation of cylinders, conversion products (oxide, metal, HF or CaF_2, ammonia, and waste), and casks. The potential impacts of this alternative were calculated by combining the impacts from each of the individual components, as appropriate. Certain impacts, such as the dose to an MEI, are not additive because the MEI at each site would be different, and the future facilities were assumed to be built at separate sites (except for the continued storage and cylinder preparation activities, which were both assumed to occur at the current storage sites; and the conversion and cylinder treatment activities, which would likely occur at the same site). The values for potential impacts estimated for the combination alternative (as discussed in the following sections) were obtained from Appendix D (Section D.4) for the continued cylinder storage component, Appendix E for the cylinder preparation component, and Appendix K (Sections K.1–K.6) for the other components.

5.7.1 Human Health and Safety — Normal Operations

5.7.1.1 Radiological Impacts

Involved Workers. The calculation of radiological impacts to involved workers is outlined below. The impacts are first presented for each of the individual components and then summed, as appropriate, to provide an estimate of the total radiological impact.

Continued Cylinder Storage. Potential radiological impacts during continued cylinder storage at the three current storage sites are the same as those previously estimated for the action alternatives (Section D.4.1.1); that is, 720 person-rem.

Cylinder Preparation. The total collective dose to involved workers would range from 835 person-rem for use of cylinder overcontainers for all cylinders from all three sites to 2,170 person-rem for transfer of all cylinders to new cylinders at the three sites (Section E. 3.1.1).

Conversion. The doses to workers from conversion for various throughput rates are provided in Figure K.5 for conversion to U_3O_8, Figure K.11 for conversion to UO_2, and in Figure K.17 for conversion to uranium metal. From these data, the estimated collective involved worker doses for conversion of 75% of the inventory to oxide and 25% to uranium metal are as follows:

Annual dose to workers from conversion of 75% of the inventory to U_3O_8
= 34 person-rem/yr

Total worker dose from conversion to U_3O_8 = 34 person–rem/yr
× 20 years = 680 person-rem

Annual dose to workers from conversion of 75% of the inventory to UO_2
= 40 to 46 person-rem/yr

Total worker dose from conversion to UO_2 = 40 to 46 person-rem/yr
× 20 years = 800 to 920 person-rem

Range for conversion of 75% of the inventory to oxide: 680–920 person-rem

Annual dose to workers from conversion of 25% of the inventory to metal
= 15 to 50 person-rem/yr

Total worker dose from conversion to metal = 5 to 50 person-rem/yr
× 20 years = 300 to 1,000 person-rem

Cylinder Treatment. The collective dose to workers from the treatment of empty cylinders for a range in the number of cylinders treated is provided in Figure K.23. It was assumed that two treatment facilities would be required, one for a 75%-capacity oxide conversion facility and one for a 25%-capacity metal conversion facility. On this basis, the estimated doses to workers are as follows:

Annual dose to workers from treatment of 75% of the cylinder inventory
= 13 person-rem/yr

Annual dose to workers from treatment of 25% of the cylinder inventory
= 7 person-rem/yr

Total worker dose from cylinder treatment = 13 + 7 person-rem/yr
× 20 years = 400 person-rem

Long-Term Storage. The doses to workers for long-term storage as oxide at various throughput rates are provided in Section K.3.1.1. From these data, the estimated collective involved worker doses for long-term storage of 50% of the inventory as oxide are as follows:

Annual dose to workers from long-term storage of 50% of the inventory as U_3O_8
= 15 person-rem/yr (from Figure K.33)

Annual dose to workers from long-term storage of 50% of the inventory as UO_2
= 9 person-rem/yr (from Figure K.31)

Range for long-term storage of 50% of the inventory as oxide
= 9 to 15 person-rem/yr × 31 years = 280 to 465 person-rem

Manufacture and Use. The doses to workers from manufacture and use for various throughput rates are provided in Figure K.41 for manufacture of UO_2-shielded casks and in Figure K.47 for manufacture of uranium metal-shielded casks. From these data, the estimated worker doses for manufacture of 25% of the inventory to oxide shielded casks and 25% to metal-shielded casks are as follows:

Annual dose to workers from manufacture of 25% of the inventory to UO_2 casks
= 10 person-rem/yr

Total worker dose from manufacture of UO_2 casks
= 10 person-rem/yr × 20 years = 200 person-rem

Annual dose to workers from manufacture of 25% of the inventory to metal casks
= 2 person-rem/yr

Total worker dose from manufacture of metal casks
= 2 person-rem/yr × 20 years = 40 person-rem

Total Radiological Impacts to Workers. The total collective radiation dose to involved workers was calculated by summing the collective doses from the individual components. The individual contributions, as well as the total dose, are summarized in Table 5.10. In addition, the number of radiation-induced health effects was estimated by multiplying the collective dose by a health risk conversion factor of 4×10^{-4} LCF/person-rem for involved workers. The total LCFs among workers were estimated to range from one to two over the duration of the program. Similar to the 100% use as oxide, 100% use as metal, and 100% long-term storage as oxide alternatives, the radiological impacts to noninvolved workers were estimated to be negligible compared with those to involved workers.

TABLE 5.10 Range of Radiological Doses and Latent Cancer Fatalities among Involved Workers for the 25% Use as Oxide, 25% Use as Metal, 50% Long-Term Storage Combination Strategy[a]

Component	Collective Dose (person-rem)
Continued cylinder storage	720
Cylinder preparation	840 – 2,200
Oxide conversion	680 – 920
Metal conversion	300 – 1,000
Cylinder treatment	400
Long-term storage	280 – 470
Manufacture of oxide casks	200
Manufacture of metal casks	40
Total dose	3,500 – 6,000
Latent cancer fatalities[b]	1 – 2

[a] Values rounded to 2 significant figures.

[b] The number of latent cancer fatalities was calculated using a health risk conversion factor of 4×10^{-4} LCF/person-rem for workers. Values rounded to one significant figure.

General Public. The collective radiation dose to members of the general public was calculated in a manner similar to that outlined above for involved workers, as follows:

Collective dose to public from continued cylinder storage (Table D.1)
= 1.1 person-rem

Collective dose to public from cylinder preparation (Tables E.1, E.2, and E.3)
= 0 to 0.006 person-rem

Collective dose to public from conversion to oxide (Figures K.1 and K.7)
= 0.6 to 9 person-rem

Collective dose to public from conversion to metal (Figure K.13)
= 0 to 3 person-rem

Collective dose to public from cylinder treatment (Figure K.19)
= 0.007 person-rem

Collective dose to public from long-term storage (Section K.3.1.2)
= approximately 0 because emissions are negligible

Collective dose to public from manufacture of oxide casks (Figure K.37)
= 0 to 0.02 person-rem

Collective dose to public from manufacture of metal casks (Figure K.43)
= 0.01 to 0.4 person-rem

The total collective dose to the public is estimated to range from approximately 1.8 to 14 person-rem. This dose would most likely result in no additional latent cancer fatalities among the public.

Because continued storage, conversion, long-term storage and manufacturing activities were assumed to occur at separate sites and the results of the parametric analyses indicate that impacts to individuals among the public would decrease with a decrease in the amount processed, the dose to general public MEIs from the combination strategy would be less than the estimates presented for the 100% use strategies in Sections 5.4 and 5.5. All doses to individual members of the general public would be well below applicable standards and regulatory limits.

5.7.1.2 Chemical Impacts

Chemical impacts to noninvolved workers and the general public from components constituting the combination strategy are generally nonadditive because these impacts were estimated for MEIs at each site and future facilities were assumed to be built at separate sites. The two exceptions are (1) continued storage and cylinder preparation activities, which would take place at the current storage sites; and (2) conversion and cylinder treatment activities, which would likely occur at the same site.

Estimated hazard indexes for MEIs for all management options are much less than 1 (a hazard index of greater than 1 indicates the potential for health impacts). The maximum hazard index for noninvolved workers and the general public for long-term storage activities is approximately 0 (Table G.5), and for manufacturing activities, it is 6.7×10^{-6} (Table H.4). To provide a conservative estimate of potential hazards from activities that would occur at the same sites, the maximum hazard index for both workers and the general public from continued cylinder storage activities for 1999 through 2039 (0.065; Tables D.5 and D.25) was added to the maximum hazard index from cylinder preparation activities (6.1×10^{-6}; Section E.3.1.2). Similarly, the maximum hazard index from conversion options (1.5×10^{-4}; Table F.6) was added to the maximum hazard index from cylinder treatment (7.1×10^{-8}; Table F.6). The results in all cases are still much lower than 1, so adverse chemical impacts from normal operations would not be associated with this combination strategy.

5.7.2 Human Health and Safety — Accident Conditions

5.7.2.1 Radiological and Chemical Impacts

For the combination strategy, the bounding impacts from accidents involving radiological or chemical releases would be the larger of the impacts estimated for the long-term storage as oxide, use as oxide, and use as metal strategies. (See Sections 5.3.1.2, 5.4.1.2, and 5.5.1.2 for detailed discussions of the impacts of these accidents.) The consequences of bounding accidents for the combination strategy would be the same as the consequences of accidents under these use strategies because about the same amount of material would be at risk of being released under accident conditions, regardless of the facility size or throughput. Although the frequencies of some accidents (for example, cylinder-handling accidents) would decrease somewhat as the facility throughput decreased, the overall frequency category for those accidents would remain the same despite these small changes in frequencies.

5.7.2.2 Physical Hazards

Physical hazards to involved and noninvolved workers were estimated by summing the injury and fatality hazards from each of the components constituting the combination strategy, similar to the method described for estimating involved worker collective radiation dose in Section 5.7.1.1. For the combination strategy, the calculations to estimate physical hazards are outlined below.

Continued Cylinder Storage. The numbers of fatalities and injuries during continued cylinder storage at the three current storage sites are the same as those previously estimated for the action alternatives (Section D.4.2.3); that is, 0.07 fatality and 90 injuries.

Cylinder Preparation. The total number of fatalities and injuries for workers would range from 0.14 fatality and 187 injuries for use of cylinder overcontainers for all cylinders from all three sites, to 0.86 fatality and 630 injuries for transfer of cylinders to new cylinders at all three sites (Section E.3.2.3). These values are estimates of the total fatalities and injuries over the entire 20-year period that cylinder preparation activities were assumed to be ongoing.

Conversion. The estimated numbers of fatalities and injuries for conversion of various throughput rates are provided in Section K.2.2.3. The estimated numbers of fatalities and injuries from conversion for the combination strategy are as follows:

Fatalities among workers from conversion of 75% of the inventory to U_3O_8
= 0.33 fatality

Fatalities among workers from conversion of 75% of the inventory to UO_2
= 0.39 to 0.57 fatality

Range for conversion of 75% of the inventory to oxide
= 0.33 to 0.57 fatality

Injuries among workers from conversion of 75% of the inventory to U_3O_8
= 270 injuries

Injuries among workers from conversion of 75% of the inventory to UO_2
= 320 to 490 injuries

Range for conversion of 75% of the inventory to oxide
= 270 to 490 injuries

Fatalities among workers from conversion of 25% of the inventory to metal
= 0.33 to 0.49 fatality

Injuries among workers from conversion of 25% of the inventory to metal
= 280 to 450 injuries

Cylinder Treatment. The estimated numbers of fatalities and injuries from the treatment of empty cylinders for a range in the number of cylinders treated is provided in Section K.2.2.3. For the combination strategy, it was assumed that one 75%-capacity treatment facility and one 25%-capacity treatment facility would likely be constructed. The estimated numbers of fatalities and injuries from cylinder treatment are as follows:

Fatalities among workers from treatment of 75% of the cylinder inventory = 0.17 fatality

Fatalities among workers from treatment of 25% of the cylinder inventory = 0.13 fatality

Injuries among workers from treatment of 75% of the cylinder inventory = 150 injuries

Injuries among workers from treatment of 25% of the cylinder inventory = 120 injuries

Total fatalities = 0.30 fatality

Total injuries = 270 injuries

Long-Term Storage. The estimated numbers of fatalities and injuries for long-term storage at various throughput rates are provided in Section K.3.2.3. From these data, the estimated values for long-term storage of 50% of the inventory as oxide are as follows:

Fatalities among workers from long-term storage of 50% of the inventory as U_3O_8
= 0.17 to 0.36 fatality

Fatalities among workers from long-term storage of 50% of the inventory as UO_2
= 0.10 to 0.19 fatality

Range for storage of 50% of the inventory as oxide = 0.10 to 0.36 fatality

Injuries among workers from long-term storage of 50% of the inventory as U_3O_8
= 114 to 176 injuries

Injuries among workers from long-term storage of 50% of the inventory as UO_2
= 76 to 110 injuries

Range for storage of 50% of the inventory as oxide = 76 to 176 injuries

Manufacture and Use. Fatalities and injuries for manufacture of UO_2- or metal-shielded casks are presented in Section K.4.2.3. The estimated numbers of fatalities and injuries for the combination strategy are as follows:

Fatalities among workers from manufacture of 25% of the inventory to UO_2 casks
= 0.60 fatality

Injuries among workers from manufacture of 25% of the inventory to UO_2 casks
= 480 injuries

Fatalities among workers from manufacture of 25% of the inventory to metal casks
= 0.70 fatality

Injuries among workers from manufacture of 25% of the inventory to metal casks
= 510 injuries

Total Physical Hazards. The total fatalities and injuries were calculated by summing the values for the individual components. The individual contributions and total fatalities and injuries are summarized in Table 5.11.

TABLE 5.11 Range of On-the-Job Fatalities and Injuries among Workers for the 25% Use as Oxide, 25% Use as Metal, 50% Long-Term Storage Combination Strategy[a]

Component	Fatalities	Injuries
Continued cylinder storage	0.07	90
Cylinder preparation	0.14 – 0.86	190 - 630
Oxide conversion	0.33 – 0.57	270 – 490
Metal conversion	0.33 – 0.49	280 – 450
Long-term storage	0.1 – 0.36	80 – 180
Cylinder treatment	0.30	270
Manufacture of oxide casks	0.60	480
Manufacture of metal casks	0.70	510
Total	3 – 4	2,200 – 3,100

[a] Represents impacts to involved and noninvolved workers from construction and operation of facilities. Values rounded to two significant figures.

5.7.3 Transportation

The transportation impacts for normal operations and traffic accident fatalities were determined by the number of shipments required for the combination strategy, assuming a travel distance of 620 miles (1,000 km) per shipment. These impacts would be the sum of the number of shipments if 25% of the inventory were converted for use as oxide, 25% of the inventory were converted for use as metal, and 50% were converted to oxide for long-term storage. As for the 100% use as oxide and 100% use as metal strategies, the impacts for exposures from normal operations (i.e., vehicular exhaust inhalation) would be no more than one fatality expected among workers and members of the general public combined. About four traffic accident fatalities would be expected for the combination strategy, about the same as expected for the 100% use as oxide or metal strategies

For the combination strategy, the bounding impacts for accidents involving releases from cylinders or releases of other materials would be the larger of the impacts estimated for the long-term storage as oxide, use as oxide, or use as metal alternative strategies. The consequences would be the same as the consequences of these strategies because the same amount of material (i.e., a single shipment) would be at risk under accident conditions, regardless of the number of shipments. The combination strategy would require approximately the same number of shipments as these strategies, so the overall probability of accidents occurring under this strategy is about the same as that for the other strategies.

5.7.4 Air Quality

Air quality impacts from construction at the current storage sites would be the same as those predicted for the no action alternative because all construction activities are planned to take place prior to about 2003, during which time all cylinders would remain at the current storage locations under all alternatives examined, including the combination strategy. Impacts during operations at the current storage sites would be the same as those predicted under the 100% use as oxide strategy (because the rate of cylinder removal would be the same under the combination strategy).

Pollutant emissions during construction and operation of conversion, long-term storage, and manufacturing facilities designed to handle 25% to 75% of the inventory would remain within standards, and would be somewhat reduced for facilities with lower throughput rates.

5.7.5 Water and Soil

Similar to the situation for air quality impacts, groundwater impacts at the current storage sites for the combination strategy would be the same as those predicted for the 100% use as oxide strategy. Potential surface water, groundwater, and soil quality impacts at conversion, long-term storage, and manufacturing facilities would be site-dependent, but, on the basis of evaluation of representative and generic sites, contaminant concentrations would be expected to remain within guideline levels. The long-term storage component of the preferred alternative could require excavating between about 41,000 yd^3 to 1.1 million yd^3 of consolidated material.

5.7.6 Socioeconomics

5.7.6.1 Continued Cylinder Storage

Socioeconomic impacts from construction activities at the current storage sites would be the same as those predicted for the no action alternative because all construction activities are planned to take place prior to about 2003, during which time all cylinders would remain at the current storage locations under the combination strategy. Impacts during operations at the current storage sites would be the same as those predicted under the 100% use as oxide strategy (because the rate of cylinder removal would be the same under the combination strategy).

5.7.6.2 Cylinder Preparation, Conversion, Long-Term Storage, and Manufacturing

Parametric socioeconomic impacts for the cylinder preparation, conversion, long-term storage, and manufacturing options were assessed qualitatively in Sections E.3.5, K.2.5, K.3.5, and K.4.5 on the basis of the preliminary cost data for the 100% cases (LLNL 1996) and socioeconomic data for parametric cases provided in a cost analysis report (LLNL 1997b). For conversion activities, the maximum estimated direct jobs and direct income values for the combination strategy calculated using the above-described data are about 1.5 times greater than estimated for the 100% use as oxide and 100% use as metal strategies, respectively. Similarly, the maximum estimated direct jobs and income for manufacturing activities under the combination strategy are about 1.5 times greater than estimated for the 100% use strategies. These differences are mainly a result of the need to construct and operate two separate conversion facilities, two separate manufacturing facilities, and a separate long-term storage facility under the combination strategy.

5.7.7 Ecology

The principal differences in ecological impacts between the combination strategy and the 100% use strategies would be associated with habitat loss at conversion, long-term storage, and manufacturing facilities. Potential habitat loss at the current storage sites is the sum of habitat loss that would occur under the no action alternative (7 acres [2.8 ha]), which would be applicable for all alternatives because construction would occur prior to 2003, and loss that would occur from cylinder preparation activities. The use of overcontainers would avoid the loss of additional habitat. Transfer facilities would range in areal site requirements from about 12 acres (4.9 ha) for a facility to process the inventory at the K-25 site (10% of the entire inventory), to 14 acres (5.7 ha) for a facility to process the inventory at the Portsmouth site (30% of the entire inventory), to 21 acres (8.5 ha) for a facility to process the inventory at the Paducah site (60% of the entire inventory) (see Section E.3.6). For alternatives involving 100% use, the maximum habitat loss at any site would be 28 acres (21 + 7) (11 ha).

Potential habitat loss for conversion facilities was calculated on the basis of data provided in Section K.2.9. The habitat loss corresponding to a 75%-capacity U_3O_8 conversion facility would be about 18 acres (7.3 ha); the loss corresponding to a 75%-capacity UO_2 conversion facility would be about 22 acres (9.0 ha). The habitat loss corresponding to a 25% capacity metal conversion facility would be 17 acres (6.8 ha). For a 75%-capacity cylinder treatment facility, the habitat loss would be about 8 acres (3.3 ha); habitat loss for a 25%-capacity cylinder treatment facility would be about 7 acres (3 ha). Although these parametric values were calculated for specific conversion options (e.g., conversion to UO_2 by the dry process, with anhydrous HF production), the amount of land required for the other conversion technologies would be roughly similar. It was assumed that two cylinder treatment facilities would be required, one for each conversion facility. The total habitat loss for conversion for the combination strategy was therefore calculated as a maximum of from 26 to 30 acres for a 75%-capacity oxide conversion facility and about 24 acres for a separate 25%-capacity metal conversion facility (total of about 50 to 54 acres).

Potential habitat loss for long-term storage facilities was estimated from data provided in Section K.3.9. For a 50%-capacity storage as oxide facility, habitat loss would be approximately 49 acres (20 ha).

Potential habitat loss for manufacturing facilities was calculated on the basis of data given in Section K.4.9. For an oxide cask manufacturing facility, the land areas corresponding to a 25%-capacity facility would be 79 acres (32 ha); the land area for a 25%-capacity metal cask manufacturing facility would be the same. Therefore, the total habitat loss for manufacturing for the combination strategy would be about 79 acres at any single site (total of about 160 acres).

5.7.8 Waste Management

For waste management at the current storage sites, impacts for the combination strategy would be similar to those estimated for the 100% use as oxide and 100% use as metal strategies.

Conversion of 100% of the inventory to either oxide or metal could have potential moderate impacts to nationwide LLW generation on the basis of a possible requirement to dispose of CaF_2 and/or MgF_2 as LLW (see Sections 5.3.7 and 5.5.7). If such disposal were required and these wastes were considered DOE waste, these strategies could generate a volume of LLW equal to about 10% of the projected DOE complexwide disposal volume. Moderate impacts to nationwide waste management are defined as additional volumes in excess of 10% of the DOE complexwide disposal volume; negligible impacts generate less than 10%. Assuming a linear decrease in potential LLW production, the combination strategy involving 75% conversion to oxide and 25% conversion to metal could have low to moderate impacts on nationwide LLW management.

The potential waste management impacts for various throughput rates for long-term storage and manufacturing facilities are discussed in Sections K.3.7 and K.4.7, respectively. Since waste management impacts for the 100% throughput rates for these facilities are generally negligible, impacts would also be negligible for the lower throughput rates considered for the combination alternative.

5.7.9 Resource Requirements

Under the combination strategy, adverse effects on local, regional, or national availability of materials would not be expected.

5.7.10 Land Use

Land use corresponds to habitat loss. See Section 5.7.7 for an explanation of the values calculated for the combination strategy.

5.7.11 Other Areas of Impact

Impacts to cultural resources at the current storage sites would depend on the selected locations for construction activities but are considered unlikely because construction would occur on land previously developed. Impacts to cultural resources at other facilities would depend on the locations and will be examined in detail at the next stage of the program when facilities are actually sited. Adverse environmental justice impacts for activities occurring under the combination strategy are not expected. The occurrence of severe transportation accidents involving a release are unlikely, and accidents occur randomly along transportation corridors; therefore, significant and disproportionate high and adverse impacts to minority or low-income populations are unlikely.

5.8 CUMULATIVE IMPACTS

Cumulative impacts are those impacts that result from the incremental impact of an action (in this case, depleted UF_6 management) when added to the impacts of other past, present, and reasonably foreseeable future actions. To conduct the cumulative impacts analysis, DOE examined those impacts associated with depleted UF_6 management activities certain to occur at the three current depleted UF_6 storage sites (Paducah, Portsmouth, and K-25 sites under all alternatives), which includes continued cylinder storage for some period for all alternatives and cylinder preparation for shipment for all alternatives except the no action alternative. To these impacts, DOE then added the impacts of other past, present, and reasonably foreseeable future actions in order to assess cumulative impacts. The USEC actions related to enrichment activities are included as a continuation of past DOE actions at the Paducah and Portsmouth sites. Non-DOE actions are considered when they will occur at one of the three depleted UF_6 storage sites, or when the nature of their impacts at locations near the three sites could increase impacts anticipated at the sites themselves.

5.8.1 Cumulative Impact Issues and Assumptions

The cumulative impact analysis considered the following impact areas for existing operations, depleted UF_6 management options, and other reasonably foreseeable future actions:

- ***Health Risk:***

  - Collective radiation dose and cancer risk for the general public over the 41-year period of depleted UF_6 operations,

  - Annual radiation dose for a hypothetical maximally exposed off-site individual,

  - Collective radiation dose and cancer risk for the worker population at a given site, and

  - Number of truck or rail shipments of radioactive materials to and from each site and the contributions to the dose to an MEI near the site gate;

- ***Environmental Quality:***

  - Potential emissions that affect air quality compared to air quality standards and

  - Potential contaminants that affect groundwater quality concentrations compared to drinking water standards or other guideline values;

- ***Resource and Infrastructure Requirements:***

  - Land requirements (presented as the percent of suitable land at each site occupied by existing facilities and needed for depleted UF_6 management activities and other future actions),

  - Percent of current water supply (presented as the percent of existing capacity needed for existing operations, depleted UF_6 management activities, and other future actions),

  - Percent of current wastewater treatment capacity (presented as the percent of existing capacity needed for existing operations, depleted UF_6 management activities, and other future actions), and

- Percent of current power capacity (presented as the percent of existing capacity needed for existing operations, depleted UF_6 management activities, and other future actions).

The health risks to the off-site population are reported as collective exposures and risks for the entire period of conducting a particular operation, while the dose to the maximally exposed individual is reported as an annual value. Annual exposures are used for the maximally exposed individual to allow a direct comparison to the DOE maximum dose limit of 100 mrem/yr exposure to an individual of the general public (MEI) from all radiation sources and exposure pathways (DOE Order 5400.5). A cumulative impacts table containing the impact categories and the major elements composing the cumulative impacts is presented for each of the three sites. These elements include the existing conditions at the site, the maximum impacts of depleted UF_6 management activities analyzed in this PEIS, and the impacts of other reasonably foreseeable future actions.

The impact categories addressed as part of the cumulative impact analysis for each of the sites are those associated with depleted UF_6 management that might generate noteworthy environmental effects when aggregated with the environmental consequences of other actions. Some impacts, such as impacts to ecological resources and cultural resources, were not included in the cumulative impact analysis because they are dependent on the specific facility location within the site boundary and location-specific environmental factors. Other impacts, such as impacts of accidents, were not included because it is highly improbable that accidents would occur together.

Cumulative impacts for the Paducah, Portsmouth, and K-25 sites were evaluated by adding the impacts of depleted UF_6 management options to the impacts of past, present, and reasonably foreseeable future actions at each site and in the region (primarily actions that DOE is considering for other programs). The latter include actions related to production and management of nuclear materials, management of nuclear fuel, research and development activities, and defense programs as described in various environmental assessments and EISs listed in Section 1.6. To assess the effects of cumulative impacts, the estimated cumulative impacts calculated for each site were compared to regulatory levels for MEI exposures, air quality standards, and drinking water standards or guidelines for these parameters. If regulatory levels or guidelines would be exceeded, then the impact could be considered significant. LCFs among the public would be considered significant if the cumulative impacts of activities at a site would yield more than 1 LCF over the 41-year period. Because radiological exposure of workers would be maintained at or below regulatory levels, resulting LCFs to those individuals would be those corresponding to acceptable radiation doses. Resources and infrastructure impacts would be considered significant if the land area required, water use, wastewater production, or power demand approached 100% of capacity for the site.

Cumulative impacts also included the consequences of recent and current environmental restoration actions. The impacts of future environmental restoration actions at the three sites were not included in the cumulative impact analysis because of insufficient characterization of the contamination and because proposals for particular actions are not yet final. Impacts of future environmental restoration activities at these sites would be analyzed in later site-specific CERCLA/RCRA program documents.

Past impacts included in the cumulative impact analysis consist of past construction, development, and environmental restoration activities that contributed to existing conditions at each site and any past activities that may have resulted in current groundwater contamination at each site; these are presented as impacts of existing operations. Although dose reconstruction studies were conducted at several DOE sites, including the Oak Ridge Reservation, these studies have not progressed to the point that would allow their incorporation in this PEIS.

No assumptions are made regarding future baseline conditions at each of the storage sites that could potentially reduce impacts, such as cessation of certain ongoing operations that would reduce current levels of radioactive releases. A number of other simplifying assumptions were made to estimate cumulative impacts regarding timing, site location, and consistency of analytical methods. Other existing or planned actions at each site were assumed to occur during the period of depleted UF_6 management operations. These other actions were assumed to be collocated with depleted UF_6 management facilities to the extent that they affect the same off-site population and MEI. These assumptions result in conservative analyses that overestimate actual cumulative impacts.

Some or most of the depleted UF_6 cylinder management activities currently occurring at the sites (and considered under existing operations) would persist during continued storage and are included in the impacts of continued storage. When estimating cumulative impacts over the 41-year assessment period, no adjustment was made for this overlap. This adds to the conservatism in the calculated cumulative collective population impacts for both the workers and members of the general public at each site.

The above simplifying assumptions could result in some differences in estimated impacts between the PEIS and site-specific documents. In addition, these simplifying assumptions and other assumptions used in performing calculations can result in some uncertainty regarding projected cumulative impacts. The cumulative impact analysis in the PEIS should be used only for evaluating the PEIS program; any site-specific analysis would supersede the PEIS cumulative analysis for that site.

5.8.2 Impacts of Continued Cylinder Storage and Preparation

This analysis focuses on potential cumulative impacts at the three sites where continued storage and cylinder preparation would occur — the Paducah, Portsmouth, and K-25 sites. For purposes of analysis, the maximum impacts estimated at each site for continued cylinder storage and cylinder preparation activities from any of the PEIS alternatives were used to provide an upper estimate of potential cumulative impacts. The three sites are discussed separately in Sections 5.8.2.1 through 5.8.2.3.

5.8.2.1 Paducah Site

Actions planned at the Paducah site include the continuation of uranium enrichment operations, waste management activities (including the Vortec vitrification system [DOE 1998b]), environmental restoration activities, and the depleted UF_6 management activities addressed in this PEIS. Actions occurring near the Paducah site that could contribute to the existing or future impacts on the site (because of their diffuse nature) include continued operation of the Tennessee Valley Authority's Shawnee power plant; the Joppa, Illinois, power plant (see DOE 1998b); and the Allied Signal uranium conversion plant in Metropolis, Illinois (NRC 1995). Table 5.12 identifies the projected cumulative impacts that could result from depleted UF_6 management activities and current activities at the Paducah site. As identified in the table, the maximum annual radioactive releases that would result from depleted UF_6 management would result in an increase in the dose to the off-site population. However, cumulative radioactive releases at the Paducah site would still be considerably below the maximum DOE dose limit of 100 mrem/yr to the off-site MEI.

The depleted UF_6 management options would be unlikely to result in additional land disturbance at Paducah because all activities are expected to occur on currently developed land. On-site infrastructure demands for water, wastewater treatment, and power would increase by at most very small amounts due to the depleted UF_6 management activities. Cumulative requirements would remain well within existing capacities.

The Paducah site is located in an attainment region where criteria air pollutants do not currently exceed regulatory standards. During construction activities at the site for continued storage or cylinder preparation, pollutant concentrations at the facility boundary would generally not exceed applicable air quality standards or guidelines. If short-term concentrations of fugitive dust emissions (PM_{10}) approached air quality standards during construction, these impacts would be temporary and could be minimized by good engineering and construction practices and standard dust suppression methods.

Data from 1996 annual groundwater monitoring showed 18 pollutants exceeding primary drinking water regulation levels in groundwater at the Paducah site: antimony, chromium, lead, nickel, nitrate, thallium, uranium, benzene, 1,2-dichloroethane, cis-1,2-dichloroethene, 1,1,-dichloroethene, ethyl benzene, tetrachloroethene, trichloroethylene, vinyl chloride, radon-222, radium-226, and technetium-99 (LMES 1997c). Fluoride has also exceeded its primary drinking water regulation level of 4 mg/L in two on-site wells (LMES 1996a).

TABLE 5.12 Cumulative Impacts of Depleted UF_6 Activities, Existing Operations, and Other Reasonably Foreseeable Future Actions at the Paducah Site, 1999 through 2039

Impact Category	Impacts of Existing Operations[a]	Maximum Impacts of Depleted UF_6 Management Activities		Impacts of Other Reasonably Foreseeable Future Actions[c]	Cumulative Impacts[d]
		Continued Storage[b]	Cylinder Preparation		
Off-site population					
Collective dose, 41 years (person-rem)	4.8	0.34	0.0030	24.6	29.7
Number of LCFs[e]	0.002	0.0002	1.5×10^{-6}	1.2×10^{-2}	0.02
Annual dose to off-site MEI[f] (mrem)	3.03	0.10	2.0×10^{-5}	1.5	4.6
Worker population					
Collective dose, 41 years (person-rem)	213	900	1,000	4.1	2,117
Number of LCFs[g]	0.09	0.37	0.40	0.0016	0.85
Transportation[h]					
Number of truck shipments, 41 years	40,836	–	28,513	6,330	75,679
Number of rail shipments, 41 years	0	–	7,129	2,410	9,539
Annual dose to MEI from truck (mrem)	3.98	–	0.0077	0.010	4.0
Annual dose to MEI from rail (mrem)	0.0	–	0.0053	0.0041	0.0094
Resources and infrastructure					
Land area (% of site)	21.9	0.0	0.6	0.53	23.0
Water use (% capacity)	50.0	0.09	0.11	0.02	50.2
Wastewater production (% capacity)	22.9	0.0	0.0	0.13	23.0
Power demand (% capacity)	51.5	0.0	0.05	0.03	51.5
Air quality[i]	None	PM_{10}	None	None	PM_{10}
Groundwater quality[j]	19 parameters[k]	Uranium-238	None	None	19 parameters[l]

[a] Includes impacts of current UF_6 generation and management activities; waste management activities; conversion of uranium ore into UF_6 at the AlliedSignal, Inc., plant in Metropolis, Illinois (NRC 1995); electrical power generation at the Tennessee Valley Authority's Shawnee power plant and at the Joppa Electric Energy, Inc., power plant (DOE 1998b); and environmental restoration activities that have proceeded to a point where their consequences can be defined: Waste Area Groupings 1 and 7 (Solid Waste Management Units C-611, C-746-K, C-740), Grouping 6 (C-400, C-403, and C-400 to C-404 underground transfer line), Grouping 15 (24—C-750, 97—C-601, 139—C-746-A1, 140—C-746-A2, 72—C-200-A, 73—C-710-B), Grouping 17 (36 different concrete rubble piles), Grouping 22 (C-404, C-747-A, C-749), and Grouping 23 (C-340, C-540-A, C-541-A, C-611, C-728, C-747-C) (LMES 1997c).

[b] The greater of either: (1) impacts from 41 years of continued storage under the No Action Alternative or (2) impacts from 20 years of continued storage under the Action Alternatives.

[c] Includes impacts related to the preferred alternative for waste management at the Paducah site (DOE 1997a); continuation of conversion of uranium ore into UF_6 at the AlliedSignal, Inc., plant at Metropolis, Illinois (NRC 1995); and treatment of mixed wastes through the Vortec vitrification system (DOE 1998b). They also consider air quality impacts from the Tennessee Valley Authority's Shawnee power plant and from the Joppa Electric Energy, Inc., power plant (DOE 1998b).

[d] Cumulative impacts equal the sum of the impacts of existing operations, depleted UF_6 management options, and other reasonably foreseeable future actions.

[e] Assumes 0.0005 LCF/person-rem.

[f] Based on LMES (1996a), which contains releases for the year 1994. Cumulative impacts assumes all facilities operate simultaneously and are located at the same point.

[g] Includes both facility and noninvolved workers. Assumes 0.0004 LCF/person-rem.

[h] The number of truck and rail shipments of radioactive materials. The MEIs (at gate) for truck and rail shipments were assumed to be different.

[i] Impacts indicate which emissions would result in nonattainment. PM_{10} = particulate matter less than or equal to 10 μm in diameter.

[j] Impacts of depleted UF_6 management activities, environmental restoration activities, or other future actions indicate whether water quality could be affected in the future.

[k] Antimony, benzene, cis-1,2-dichloroethene, chromium, 1,2-dichloroethane, 1,1-dichloroethene, ethyl benzene, fluoride, lead, nickel, nitrate, radium-226, radon-222, technetium-99, tetrachloroethene, thallium, trichloroethylene, uranium, and vinyl chloride.

[l] Only 19 parameters are shown rather than 20 because uranium is included in more than one column (i.e., it is in existing operations as well as continued storage).

Sources: LMES (1996a; 1997c), DOE (1997a; 1998b), and NRC (1995).

During continued storage of depleted UF_6, releases from breached cylinders could result in increased concentrations of uranium in the groundwater. If current cylinder maintenance programs control continued cylinder corrosion, the groundwater analysis indicates that the maximum uranium concentration in groundwater (from cylinder breaches) would be 6 μg/L, considerably below the 20 μg/L guideline level used for comparison (EPA 1996). If no credit is taken for reduced cylinder corrosion rates from painting and maintenance, cylinder breaches occurring at Paducah before the year 2020 could result in groundwater concentrations of uranium exceeding 20 μg/L in the future.

5.8.2.2 Portsmouth Site

Actions planned at the Portsmouth site include the continuation of existing operations, waste management activities, environmental restoration activities, and the depleted UF_6 management activities addressed in this PEIS. Table 5.13 identifies the projected cumulative impacts that could result from future depleted UF_6 management activities and current activities at Portsmouth. As identified in the table, the maximum annual radioactive releases associated with depleted UF_6 management activities would result in a very slight increase in the radiation dose to the off-site population. However, cumulative radioactive releases would still be considerably below the DOE dose limit of 100 mrem/yr to the off-site MEI.

The depleted UF_6 management activities would be unlikely to result in any additional land disturbance at Portsmouth because all activities are expected to occur on currently developed land. On-site infrastructure demands for water, wastewater treatment, and power would increase by at most very small amounts due to depleted UF_6 management activities. Cumulative requirements would remain well within existing capacities.

The Portsmouth site is located in an attainment region where criteria air pollutants do not currently exceed regulatory standards. During construction activities at the site for continued storage or cylinder preparation, pollutant concentrations at the facility boundary would generally not exceed applicable air quality standards or guidelines. If short-term concentrations of fugitive dust emissions (PM_{10}) approached air quality standards during construction, these impacts would be temporary and could be minimized by good engineering and construction practices and standard dust suppression methods.

On the basis of data from 1996 annual groundwater monitoring, 11 pollutants have been found to exceed primary drinking water regulation levels in groundwater at the Portsmouth site: chromium, uranium, chloroform, cis-1,2-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,-dichloroethene, Freon-113, 1,1,1-trichloroethane, trichloroethylene, and vinyl chloride (LMES 1997d). Elevated levels of technetium-99 have also been detected in groundwater.

TABLE 5.13 Cumulative Impacts of Depleted UF_6 Activities, Existing Operations, and Other Reasonably Foreseeable Future Actions at the Portsmouth Site, 1999 through 2039

Impact Category	Impacts of Existing Operations[a]	Maximum Impacts of Depleted UF_6 Management Activities: Continued Storage[b]	Maximum Impacts of Depleted UF_6 Management Activities: Cylinder Preparation	Impacts of Other Reasonably Foreseeable Future Actions[c]	Cumulative Impacts[d]
Off-site population					
Collective dose, 41 years (person-rem)	1.2	0.05	0.001	0.0054	1.3
Number of LCFs[e]	0.001	0.00002	6.0×10^{-7}	2.7×10^{-6}	6.3×10^{-4}
Annual dose to off-site MEI[f] (mrem)	0.066	0.02	4.5×10^{-5}	6.8×10^{-5}	0.069
Worker population					
Collective dose, 41 years (person-rem)	7,000	380	690	14.6	8,085
Number of LCFs[g]	2.80	0.16	0.28	0.0058	3.2
Transportation[h]					
Number of truck shipments, 41 years	10,660	–	13,421	34,090	58,171
Number of rail shipments, 41 years	8,815	–	3,356	13,000	25,171
Annual dose to MEI from truck (mrem)	1.04	–	0.0036	0.055	1.10
Annual dose to MEI from rail (mrem)	0.86	–	0.0025	0.021	0.88
Resources and infrastructure					
Land area (% of site)	21.6	0.0	0.6	0.34	22.5
Water use (% capacity)	36.8	0.07	0.07	0.06	37.0
Wastewater production (% capacity)	81.1	0.0	0.0	0.65	81.8
Power demand (% capacity)	79.2	0.0	0.06	0.11	79.4
Air quality[i]	None	None	None	None	None
Groundwater quality[j]	12 parameters[k]	None	None	None	12 parameters[k]

[a] Includes impacts of current UF_6 generation and management activities, waste management activities, environmental restoration activities that have proceeded to a point where their consequences can be defined (Peter Kiewit landfill, X-611A lime salvage lagoons, X-749/X-120 interim action, X-705A/B soil removal action, sitewide drainage ditches), and the components of the experimental Technology Applications Program applied at the Portsmouth site (X-231B oil biodegradation plot technology demonstration field tests, X-701B in situ chemical oxidation, X-701B surfactant studies, X-623 inorganic photo catalytic membrane treatment study, X-231A soil fracturing demonstrations, X-625 passive groundwater treatment through reactive media, in situ radiological decontamination demonstration in X-326, TechXtract™ surface decontamination process) (Bechtel Jacobs Company LLC 1998b).

[b] The greater of either: (1) impacts from 41 years of continued storage under the No Action Alternative or (2) impacts from 20 years of continued storage under the Action Alternatives.

[c] Includes impacts related to the preferred alternative to waste management at the Portsmouth site (DOE 1997a).

[d] Cumulative impacts equal the sum of the impacts of existing operations, depleted UF_6 management options, and other reasonably foreseeable future actions.

[e] Assumes 0.0005 LCF/person-rem.

[f] Based on LMES (1996b), which contains releases for the year 1994. Cumulative impacts assumes all facilities operate simultaneously and are located at the same point.

[g] Includes both facility and noninvolved workers. Assumes 0.0004 LCF/person-rem.

[h] The number of truck and rail shipments of radioactive materials. The MEIs (at gate) for truck and rail shipments were assumed to be different.

[i] Impacts indicate which emissions would result in nonattainment.

[j] Impacts of depleted UF_6 management activities, environmental restoration activities, or other future actions indicate whether water quality could be affected in the future.

[k] Chloroform, chromium, cis-1,2-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, Freon-113, technetium-99, 1,1,1-trichloroethane, trichloroethylene, uranium, and vinyl chloride.

Sources: LMES (1996b, 1997d), DOE (1997a), and Bechtel Jacobs Company LLC (1998b).

During continued storage of depleted UF_6, releases from breached cylinders could result in increased concentrations of uranium in the groundwater. If current cylinder maintenance programs control continued cylinder corrosion, the groundwater analysis indicates that the maximum uranium concentration in groundwater (from cylinder breaches) would be 5 µg/L, considerably below the guideline level used for comparison, 20 µg/L (EPA 1996). If no credit is taken for reduced cylinder corrosion rates from painting and maintenance, cylinders would have to undergo uncontrolled corrosion until about 2050 before groundwater concentrations of uranium would approach 20 µg/L in the future. The groundwater concentration would not actually reach 20 µg/L until later than the year 2100.

5.8.2.3 Oak Ridge Reservation: K-25 Site

This analysis considers all actions on the Oak Ridge Reservation and is not limited to the K-25 site alone, except where specified. Aside from the continuation of existing operations and depleted UF_6 management activities, reasonably foreseeable future actions at the Oak Ridge Reservation include waste management activities (DOE 1997a), stockpile stewardship and management activities (DOE 1996c), storage and disposition of weapons-usable fissile materials (DOE 1996i), the disposition of highly enriched uranium (DOE 1996a), interim storage of enriched uranium (DOE 1994c), the transfer of nonnuclear functions (DOE 1993), changes in the sanitary sludge land application program (DOE 1996i), proposed reindustrialization of the K-25 site as the East Tennessee Technology Park (DOE 1997b), and environmental restoration activities at the K-25 site (DOE 1997c). Many of these future actions would take place at the other two sites (Y-12 and ORNL) at the Oak Ridge Reservation. However, because of the overlapping region of influence, except for cases where available data preclude a reservationwide view, the cumulative impacts for K-25 generally include the impacts for the Oak Ridge Reservation as a whole.

Table 5.14 identifies the projected cumulative impacts that would result from the two depleted UF_6 management activities that would occur at the K-25 site, existing activities, and planned actions described in the aforementioned EISs. The off-site MEI is specific to K-25. As identified in the table, annual radioactive releases would increase as a result of releases from the depleted UF_6 management activities, depleted UF_6 transport, and other possible actions associated with the Oak Ridge Reservation. However, maximum cumulative radioactive releases would remain below the DOE dose limit of 100 mrem/yr to the off-site MEI.

Depleted UF_6 management activities would affect a maximum of about 7 additional acres (2.8 ha) at K-25, while other actions could affect another 975 acres (390 ha). This area is about 13.9% of the total suitable acreage at K-25. The demand for water, wastewater, and power at the Oak Ridge Reservation would not be greatly affected by depleted UF_6 activities that would occur at K-25. Cumulatively, water, wastewater, and power facilities at the Oak Ridge Reservation would not require major improvements (expansions or upgrades) because projected cumulative future demand is less than existing capacities.

TABLE 5.14 Cumulative Impacts of Depleted UF_6 Activities, Existing Operations, and Other Reasonably Foreseeable Future Actions at the Oak Ridge Reservation, 1999 through 2039

Impact Category	Impacts of Existing Operations[a]	Maximum Impacts of Depleted UF_6 Management Activities: Continued Storage[b]	Maximum Impacts of Depleted UF_6 Management Activities: Cylinder Preparation	Impacts of Other Reasonably Foreseeable Future Actions[c]	Cumulative Impacts[d]
Off-site population					
Collective dose, 41 years (person-rem)	1,763	0.34	0.002	21.4	1,780
Number of LCFs[e]	0.88	0.0004	1.0×10^{-6}	0.011	0.89
Annual dose to off-site MEI[f] (mrem)	9.82	0.46	3.0×10^{-5}	0.62	10.8
Worker population					
Collective dose, 41 years (person-rem)	2,788	200	480	3,400	6,880
Number of LCFs[g]	1.12	0.08	0.19	1.36	2.75
Transportation[h]					
Number of truck shipments, 41 years	42,640	–	4,732	70,834	118,206
Number of rail shipments, 41 years	328	–	1,183	26,000	27,511
Annual dose to MEI from truck (mrem)	4.2	–	0.0013	0.20	4.4
Annual dose to MEI from rail (mrem)	0.032	–	0.0009	0.068	0.10
Resources and infrastructure					
Land area (% of site)[i]	26.0	0.14	0.4	13.9	40.5
Water use (% capacity)	45.5	0.01	0.05	0.5	46.1
Wastewater production (% capacity)[j]	69.6	0.0	0.0	17.2	86.8
Power demand (% capacity)[j]	10.9	0.0	0.09	21.8	32.8
Air quality[k]	None	PM_{10}, HF	None	None	PM_{10}, HF
Groundwater quality[l]	24 parameters[m]	Uranium-238	None	6 parameters[n]	27 parameters[o]

[a] Includes impacts of current UF_6 management activities, waste management activities, and environmental restoration activities (at K-25) that have proceeded to a point where their consequences can be defined: Watershed I, Watershed II, Watershed III, Watershed IV, Watershed V, Watershed VI, and non-Watershed Areas (individual projects listed in DOE 1997c).

[b] The greater of either: (1) impacts from 41 years of continued storage under the No Action Alternative or (2) impacts from 20 years of continued storage under the Action Alternatives.

[c] These include impacts from EISs related to (1) stockpile stewardship and management (DOE 1996c), (2) storage and disposition of weapons-usable fissile materials (DOE 1996d), (3) disposition of surplus highly enriched uranium (DOE 1996a), (4) transfer of nonnuclear functions (DOE 1993), (5) waste management (DOE 1997a), (6) proposed changes in the sanitary sludge land application program (DOE 1996i), and (7) potential reindustrialization of the K-25 site (DOE 1997b). Impacts of reasonably foreseeable future actions do not include the potential environmental impacts of constructing and operating a proposed CERCLA waste management facility or the potential impacts of constructing and operating a barge facility, both of which will be estimated in the future at a time closer to the development of those two facilities (see DOE 1997b).

[d] Cumulative impacts equal the sum of the impacts of existing operations, depleted UF_6 management options, and other reasonably foreseeable future actions.

[e] Assumes 0.0005 LCF/person-rem.

[f] MEI at K-25. Based on LMES (1995a), which contains releases for the year 1994. Cumulative impacts assumes all facilities operate simultaneously and are located at the same point.

[g] Includes both facility and noninvolved workers. Assumes 0.0004 LCF/person-rem.

[h] The number of truck and rail shipments of radioactive materials. The MEIs (at gate) for truck and rail shipments were assumed to be different.

[i] Land area impacts are determined on the basis of the K-25 site area of 4,845 acres (1,961 ha) (including undeveloped sections) rather than the total Oak Ridge Reservation area of 34,516 acres (13,974 ha), since Oak Ridge Reservation consists of three main areas of activity separated by large tracts of a National Environmental Research Park that will largely remain undeveloped.

[j] Considers K-25 only.

[k] Impacts indicate which emissions would result in nonattainment. PM_{10} = particulate matter less than or equal to 10 μm in diameter.

[l] Existing groundwater quality impacts are for the K-25 site only. Impacts of depleted UF_6 management activities, environmental restoration activities, or other future actions indicate whether water quality could be affected.

[m] Antimony, arsenic, barium, benzene, cadmium, carbon tetrachloride, chloroform, chromium, 1,1-dichloroethene, 1,2-dichloroethene, fluoride, lead, methylene chloride, nickel, technetium-99, tetrachloroethene, thallium, toluene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethylene, 1,1,2-trichloro-1,2,2-trifluoroethane, uranium, and vinyl chloride.

[n] 1,2-Dichloroethane, methylene chloride, plutonium-239, plutonium-240, technetium-99, and uranium-238.

[o] Only 27 parameters would be exceeded instead of 31 because methylene chloride, technetium-99, and uranium could be exceeded under existing operations, continued storage, and as a result of other future actions (i.e., they are included in more than one column).

Sources: LMES (1996c, 1996d); DOE (1997a).

The Oak Ridge Reservation is located in an attainment region where criteria air pollutants do not currently exceed regulatory standards. For construction activities at the K-25 site for continued storage or cylinder preparation, pollutant concentrations at the facility boundary would generally not exceed applicable air quality standards or guidelines. If short-term concentrations of fugitive dust emissions (PM_{10}) approached air quality standards during construction, these impacts would be temporary and could be minimized by good engineering and construction practices and standard dust suppression methods.

If current cylinder maintenance programs control continued cylinder corrosion, the air analysis indicates that the maximum HF concentration at the site boundary could reach a maximum of 23% of the standard. However, if no credit is taken for control of corrosion, the HF concentration could approach the primary standard concentration of 29 $\mu g/m^3$ (24-hour average) around the year 2020.

On the basis of data from 1994 and 1995 annual groundwater monitoring, 23 pollutants have been found to exceed primary drinking water regulation levels in groundwater at the K-25 site: antimony, arsenic, barium, cadmium, chromium, fluoride, lead, nickel, thallium, uranium (as estimated from gross alpha levels), benzene, carbon tetrachloride, chloroform, 1,1,-dichloroethene, 1,2-dichloroethene, methylene chloride, tetrachloroethene, toluene, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethylene, and vinyl chloride (LMES 1995a; 1996d). Gross beta levels (possibly indicative of technetium-99) also exceeded the standard. Another six pollutants could affect groundwater quality as a result of reasonably foreseeable future actions; these are 1,2-dichloroethane, methylene chloride, plutonium-239, plutonium-240, technetium-99, and uranium-238.

During continued storage of depleted UF_6, releases from breached cylinders could result in increased concentrations of uranium in the groundwater. If current cylinder maintenance programs control continued cylinder corrosion, the groundwater analysis indicates that the maximum uranium concentration in groundwater (from cylinder breaches) would be 7 $\mu g/L$, considerably below the 20 $\mu g/L$ guideline level used for comparison (EPA 1996). If no credit is taken for reduced cylinder corrosion rates from painting and maintenance, cylinders would have to undergo uncontrolled corrosion until about 2025 before groundwater concentrations of uranium would approach 20 $\mu g/L$ in the future. The groundwater concentration would not actually reach 20 $\mu g/L$ until later than the year 2100.

5.8.3 Impacts of Facility Colocation

The cumulative impact analyses presented in Section 5.8.2 were based on the assumption that long-term storage, conversion, and disposal facilities would not be colocated with storage and cylinder preparation facilities and therefore would not be placed at any of the three current cylinder storage sites. However, colocation of facilities at these sites is a possibility for certain alternatives. Table 5.15 lists the most probable colocation scenarios for the alternatives considered in this PEIS,

TABLE 5.15 Potential Colocation of Facilities and the Alternatives Affected

Facilities	Alternatives
Continued storage + Conversion	Long-term storage as oxide Disposal Use as oxide and metal Preferred alternative
Continued storage + Conversion + Long-term storage as oxide	Long-term storage as oxide Preferred alternative
Continued storage + Long-term storage as UF_6	Long-term storage as UF_6

scenarios that involve the addition of one or more facilities to the sites where current storage already is under way. A detailed analysis of potential impacts resulting from colocation would be the subject of site-specific Phase II NEPA reviews. One positive result of colocation would be the elimination of impacts associated with transporting material between sites that have been colocated. In this PEIS, effects associated with shipping depleted UF_6, either in original form or a converted form, can involve site-specific and non-site-specific issues. The former concerns activities associated with the preparation of material for shipping, most notably impacts considered under cylinder preparation activities that occur at the current storage site prior to transporting depleted UF_6 elsewhere. Non-site-specific issues, in contrast, primarily concern the shipment of material (depleted UF_6 in either original or a converted form) from one site to another. The reduction of impacts associated with the actual transport of material can yield advantages since these impacts are among the largest of the impacts associated with particular alternatives.

5.9 ISSUES RELATED TO POTENTIAL LIFE-CYCLE IMPACTS

All of the PEIS alternatives, except for disposal as uranium oxide, would require the continued management of depleted uranium beyond 2039, the time period addressed in detail in the PEIS. With the exception of potential long-term groundwater impacts from continued cylinder storage and disposal, the potential environmental impacts of management activities beyond 2039 were not evaluated in the PEIS because the specific actions that would take place are considered highly uncertain and speculative and are not ready for decision at this time. However, this section discusses issues related to the potential life-cycle impacts associated with depleted uranium management.

If a long-term storage alternative (no action, long-term storage as UF_6, or long-term storage as oxide) is selected in the Record of Decision for the PEIS, several actions could occur beyond

2039: the depleted uranium could continue to be stored, it could be used or disposed of, or it could be converted to another chemical form and used or disposed of.

The continued storage of depleted uranium beyond 2039 may require the replacement or refurbishment of storage containers and facilities as their design lifetimes are exceeded. The extent of such activities would depend heavily on the environmental storage conditions, maintenance performed, performance and condition of the containers and facilities over time, and applicable regulatory requirements at that time. With proper monitoring and maintenance and with replacement and refurbishment as needed, storage could, in theory, continue indefinitely with minimal impacts to workers and the environment.

If a decision is made in the future to use or dispose of the depleted uranium in storage, it is possible that conversion to a different chemical form may be required. For example, if the depleted uranium is stored as UF_6, conversion to uranium oxide or uranium metal may be necessary before use. Similarly, disposal may also require conversion to a suitable chemical form, such as uranium oxide. Such activities would depend on the nature of the uses identified in the future and the applicable regulatory requirements at the time of disposal.

If a use alternative is implemented (use as oxide, use as metal, or a combination such as in the preferred alternative), depleted uranium might also require management after use. After use, products containing depleted uranium could potentially be stored, reused, recycled for other uses, or they could be treated (e.g., converted to another chemical form) and disposed of as LLW. The ultimate fate of the depleted uranium after use would depend in part on market demand, economic considerations, and the applicable regulatory requirements at that time.

If the decision is made to dispose of depleted uranium products after use, treatment may be necessary. If the depleted uranium is used in the form of uranium oxide, treatment requirements would likely be minimal (e.g., volume reduction and packaging as needed) because uranium oxide is the current preferred chemical form for disposal. More extensive treatment may be required if the depleted uranium is used in the form of uranium metal. Current regulatory criteria restrict the chemical form for disposal. Reactive waste forms, such as depleted uranium metal, are specifically excluded from disposal at the two DOE LLW disposal sites at the Nevada Test Site and the Hanford Site. Current waste acceptance criteria would likely need to be relaxed before disposal of bulk quantities of uranium metal could occur. Conversely, uranium metal could be converted to uranium oxide before disposal, and a conversion facility would likely be required.

Some uses might also result indirectly in the permanent disposal of the material. For example, casks containing depleted uranium could be used as part of a disposal package for spent nuclear fuel or HLW in a geologic repository. Pursuant to the Nuclear Waste Policy Act, DOE is currently characterizing the Yucca Mountain site in Nevada as a potential repository for spent nuclear fuel and HLW. Only casks that met the acceptance criteria of such a repository would be used for disposal. In addition, future uses may also consume the depleted uranium as fuel in advanced nuclear reactors, with the resulting spent nuclear fuel disposed of accordingly.

5.10 MITIGATION

The impacts of the alternatives presented in this chapter are primarily the maximum impacts expected for the range of options included within each alternative. Factors such as flexibility in siting and collocation, technology selection, and facility design and construction could be used to reduce impacts from these maximum levels. This section identifies what impacts could be mitigated to reduce adverse impacts. The assessment of specific technologies, siting considerations, and facility design and construction are issues that will be addressed in Phase II NEPA reviews and future decisions related to siting, technology selection, or facility construction and operations. However, based on the analyses conducted for this PEIS, the following recommendations can be made:

- Temporary impacts on air quality from dust emissions during construction of any new facility should be controlled by the best available practice to avoid temporary exceedances of the PM_{10} standard.

- Eventual impacts on air and groundwater at the current storage sites should be avoided by cylinder inspection, cylinder maintenance (such as painting), and prompt cleanup of any releases from any breached depleted UF_6 cylinders. Additionally, collection and sampling of runoff from cylinder yards should allow detection of contaminant releases to avoid releases to surface water or groundwater.

- Future impacts on groundwater from failure of a disposal facility could be minimized by selection of a site in a dry environmental setting.

- If a new mine were to be used for long-term storage or disposal, tailings from the excavation would be disposed of at the surface. These tailings should be graded to be compatible with existing topography and surrounding land uses and revegetated with native species or species compatible with the surrounding environment.

Although the probability of transportation accidents involving hazardous chemicals such as HF and ammonia is very low, the consequences could be severe. The colocation of facilities could minimize the amount of transportation required and could reduce this risk. For this PEIS, the assessment of transportation accidents involving anhydrous HF assumed conservative conditions. Currently, a number of industry practices are commonly employed to minimize the potential for large HF releases, as discussed below.

Anhydrous HF is usually shipped in 100-ton, 23,000-gal (91-metric ton, 87,000-L) shell, full, noncoiled, noninsulated tank cars. Most HF railcars today meet the DOT classification 112S500W, which represents the current state-of-the-art. To minimize the potential for accidental releases, these railcars have head shields and employ shelf couplers, which assist in avoiding punctures during an accident. The use of these improved state-of-the-art tank cars has led to an improved safety record with respect to HF accidents over the last several years. The HF transportation accident rate has steadily decreased since 1985. Industry recommendations for the new tank car guideline appear in *Recommended Practices for the Hydrogen Fluoride Industry* (Hydrogen Fluoride Industry Practices Institute 1995b).

Accidents involving anhydrous HF and ammonia at a conversion facility were estimated to have potentially serious consequences. A wide variety of good engineering and mitigative practices are available that affect siting, design, and accident mitigation for HF or ammonia storage tanks, such as might be present at a conversion facility. Many are summarized in *Guideline for the Bulk Storage of Anhydrous Hydrogen Fluoride* (Hydrogen Fluoride Industry Practices Institute 1995a). There is an advanced set of accident prevention and mitigative measures that are recommended by industry for HF storage tanks, including storage tank siting principles (e.g., evaluating seismic and high wind conditions or drainage conditions), design recommendations, and tank appurtenances, as well as spill detection, containment, and mitigation. Measures to mitigate the consequences of an accident include anhydrous HF detection systems, spill containment systems such as dikes, remote storage tank isolation valves, water spray systems, and rapid acid deinventory systems (removing acid rapidly from a leaking vessel). Details on these mitigative strategies are also provided in the Hydrogen Fluoride Industry Practices Institute (1995a) guidelines.

5.11 UNAVOIDABLE ADVERSE IMPACTS

Unavoidable adverse impacts are those impacts that cannot be mitigated by strategy selection and future considerations of technology selection, siting, and facility construction. Some impacts would be unavoidable, no matter which strategy were selected.

The depleted UF_6 cylinders currently in storage would require continued monitoring and maintenance for all alternatives. These activities would result in exposures of workers to low levels of radiation in the vicinity of the cylinders. The radiation exposure of workers can be minimized, but some level of exposure is unavoidable. The radiation doses to workers were estimated to be well within public health standards for all alternatives. Radiation exposures of workers would be monitored at each facility and would be kept as low as reasonably achievable. Cylinder monitoring and maintenance activities would also produce emissions of air pollutants, such as vehicle exhaust and dust (PM_{10}), and produce small amounts of sanitary waste and LLW. Concentrations of air emissions during operations were estimated to be within applicable standards and guidelines, and waste generation would not appreciably affect waste management operations.

All alternatives would involve a potential for accidental on-the-job injuries and fatalities among workers, unrelated to radiation or chemical exposures. These impacts are a consequence of unanticipated events in the work environment, typical of all work places. Based on statistics in similar industries, from 1 to 4 accidental fatalities and up to several thousand worker injuries were estimated for the PEIS alternatives. The chance of fatalities and injuries occurring would be minimized by conducting all work activities in as safe a manner as possible, in accordance with occupational health and safety rules and regulations. However, the chance of these type of impacts cannot be completely avoided.

All alternatives other than the no action alternative might require the construction of new facilities, for purposes of cylinder preparation, conversion, long-term storage, or disposal. Up to several hundred acres could be required for some alternatives. Construction of new facilities could result in losses of terrestrial and aquatic habitats. Dispersal of wildlife and temporary elimination of habitats would result from land-clearing and construction activities involving movement of construction personnel and equipment. The construction of new facilities could cause both short-term and long-term disturbances of previously undisturbed biological habitats. Although some destruction would be inevitable during and after construction, these losses would be minimized by careful site selection and thorough environmental reviews at a site-specific level.

5.12 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The major irreversible and irretrievable commitments of natural and man-made resources related to the alternative management strategies for depleted UF_6 that can be identified at this programmatic level of analysis are discussed in Sections 5.12.1 through 5.12.3. A commitment of resources is irreversible when its primary or secondary impacts limit the future options for a resource. An irretrievable commitment refers to the use or consumption of resources neither renewable nor recoverable for later use by future generations.

The programmatic decisions resulting from this PEIS would commit resources required for implementing the selected alternative. Three major resource categories would be committed irreversibly or irretrievably under the alternative management strategies considered in this PEIS: land, materials, and energy.

5.12.1 Land

Land that is currently occupied by or ultimately selected for UF_6 cylinder storage or potential conversion, manufacture, or long-term storage facilities could ultimately be returned to open space if the yards, buildings, roads, and other structures were removed, areas cleaned up, and the land revegetated. Future use of these tracts of land, although beyond the scope of this PEIS, could include restoring those areas for unrestricted use. Therefore, commitment of this land is not necessarily irreversible. However, land set aside for radioactive, hazardous, and chemical waste disposal represents an irretrievable commitment because wastes in belowground disposal areas could not be completely removed, the land could not be restored to its original condition or to minimum cleanup standards, nor could the site be feasibly used for any other purposes following closure of the disposal facility. The disposal facilities evaluated in this PEIS could require up to 470 acres (188 ha). This land would be permanently unusable because the ground would no longer be suitable for intrusive activities, such as mining or utilities. The surface area appearance and biological habitat potentially lost during construction and operation of the disposal facilities could, however, be restored to a large extent.

5.12.2 Materials

The irreversible and irretrievable commitment of material resources for the various PEIS alternatives includes construction materials that could not be recovered or recycled, materials rendered radioactive that could not be decontaminated, and materials consumed or reduced to unrecoverable forms of waste. Where construction was necessary, materials required would include wood, concrete, sand, gravel, steel, aluminum, and other metals. At this time, no unusual construction material requirements have been identified. The construction resources, except for those that could be recovered and recycled with current technology, would be irretrievably lost. None of the identified construction resources is in short supply, and all should be readily available. Consumption of operating supplies such as paper, miscellaneous chemicals such as sodium hydroxide, and gases such as argon and nitrogen, although irretrievable, would not constitute a permanent drain on local sources or involve any material in critically short supply in the United States as a whole. Strategic and critical materials (e.g., Monel and Inconel) would not be required in quantities that would seriously reduce the national or world supply.

Any decision to dispose of depleted uranium without prior application as a use option would represent an irretrievable commitment of a potential material resource. Disposal is by definition irreversible, and the depleted uranium would be lost forever as a material resource.

5.12.3 Energy

The irretrievable commitment of energy resources during construction and operations of the various facilities considered by the alternatives would include the consumption of fossil fuels used to generate heat and electricity for the facilities. Energy would also be expended in the form of diesel fuel, gasoline, and oil for construction equipment and transportation vehicles. Under the long-term storage as UF_6, long-term storage as oxide, and disposal alternatives, options involving mine storage or disposal would require large quantities of electrical energy during construction (up to 1,100 MW-yr). The availability of this electricity would depend on site location.

Any decision to dispose of depleted uranium would represent an irretrievable commitment of a potential energy resource. Depleted uranium is a potential fuel for future nuclear breeder reactors. Disposal is by definition irreversible, and the depleted uranium would be lost forever as a potential energy resource.

5.13 RELATIONSHIP BETWEEN SHORT-TERM USE OF THE ENVIRONMENT AND LONG-TERM PRODUCTIVITY

For this PEIS, short term was considered the period of construction activities for the alternative management strategies — the time when most short-term (or temporary) environmental impacts would occur. Most alternatives would require the use of additional land. Such use would remove this land from other beneficial uses until at least the year 2040 because of the presence of long-term hazards. Disposal of solid nonhazardous waste generated from new facility construction and operations would require additional land at a sanitary landfill site, which would be unavailable for other uses in the long term. Any LLW generated by the various alternatives would involve the commitment of associated land, transportation, processing facilities for waste management, and disposal resources.

For those alternatives involving the construction and operation of new facilities, the associated construction activities would result in both short-term and long-term losses of terrestrial and aquatic habitats from natural productivity. Dispersal of wildlife and temporary elimination of habitats would result from land clearing and construction activities involving movement and staging of construction personnel and equipment. The building of new facilities could cause long-term disturbances of previously undisturbed biological habitats, potentially causing long-term reductions in the biological activity of an area. Although some habitat loss would be inevitable during and after construction, these losses would be minimized by careful site selection and by thorough environmental reviews at a site-specific level. Short-term impacts would be reduced and mitigated as necessary. After closure of the new facilities (beyond 40 years), they would be decommissioned and could be reused, recycled, or remediated.

5.14 POLLUTION PREVENTION AND WASTE MINIMIZATION

Implementation of any of the PEIS alternatives would be conducted in accordance with all applicable pollution prevention and waste minimization guidelines. Pollution prevention utilizes source reduction techniques in order to reduce risk to public health, safety, welfare, and the environment, and environmentally-acceptable recycling to achieve these same goals. The *Pollution Prevention Act* of 1990 (42 USC 11001-11050) established a national policy that pollution should be prevented or reduced at the source, whenever feasible. Under the Act, pollution that cannot be prevented should be recycled in an environmentally safe manner. Disposal or other releases into the environment should only be employed as a last resort. Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements" (U.S. President 1993), and DOE Order 5400.1, "General Environmental Protection Program," implement the provisions of the *Pollution Prevention Act* of 1990. DOE has established goals for reducing the generation and release of toxic chemicals, all types of waste, and pollutants. These waste-reduction goals (to be achieved by December 31, 1999) use calendar year 1993 as the baseline year for measuring progress. *The 1996 Pollution Prevention Program Plan* (DOE 1996f) was issued by the Secretary of Energy on May 3, 1996, to serve as the principal crosscutting guidance to DOE Headquarters, DOE Operations Offices, the national laboratories, and contractors to fully implement pollution prevention programs within the DOE complex that would reduce DOE's routine generation of radioactive, mixed, and hazardous wastes, and total releases, and off-site transfers of toxic chemicals. Pollution prevention measures could include source reduction, recycling, treatment, and disposal. The emphasis is on source reduction and recycling to prevent the creation of wastes, i.e., waste minimization.

Waste minimization is the reduction, to the extent feasible, of the generation of radioactive and hazardous waste. Source reduction and waste minimization techniques include good operating practices, technology modifications, input material changes, and product changes. An example of facilitating waste minimization is to substitute nonhazardous materials, where possible, for those materials that contribute to the generation of hazardous or mixed waste.

Many of the facilities considered by the PEIS alternatives are still in the conceptual stages of the engineering and design process. Consideration of opportunities to reduce waste generation at the source, as well as for material recycle and reuse, will be incorporated to the extent possible into the engineering and design process for the selected alternative. Examples of pollution prevention and waste minimization concepts that have been incorporated into the PEIS alternatives include the following:

- A cylinder treatment facility (including removal of residual radioactive contamination [i.e., "heels"] from the cylinders) option was included to allow potential final disposition of empty UF_6 cylinders (after removal of the depleted UF_6 contained within them) to become part of the scrap metal inventory at the gaseous diffusion plant sites and to possibly avoid disposal of the empty UF_6 cylinders as LLW.

- The MgF_2 by-product from conversion of depleted UF_6 into uranium metal would be leached with nitric acid to reduce its level of uranium contamination, which might allow disposal of the MgF_2 in a sanitary landfill.

- Wastes such as paper, aluminum, and other items generated during facility operations were assumed to be collected for pickup by recycling organizations and not disposed of as sanitary waste.

Pollution prevention and waste minimization would be major factors in determining the final design of any facility constructed as part of the decision of a selected PEIS alternative. Specific pollution prevention and waste minimization considerations will be analyzed as part of the Phase II studies and NEPA reviews following the Record of Decision for the PEIS.

6 IMPACTS ASSOCIATED WITH MANAGING CYLINDERS OF USEC-GENERATED DEPLETED UF_6*

After the draft PEIS was completed, management responsibility for approximately 11,400 cylinders of depleted UF_6 (about 137,000 metric tons) was transferred from USEC to DOE by the signing of two MOAs associated with the privatization of USEC. The *Memorandum of Agreement Relating to Depleted Uranium Generated Prior to the Privatization Date* (DOE and USEC 1998a), signed in May 1998, transferred management responsibility for approximately 9,400 cylinders from USEC to DOE, with about 6,600 of the cylinders stored at Paducah and about 2,800 stored at Portsmouth. The *Memorandum of Agreement Relating to Depleted Uranium* (DOE and USEC 1998b), signed in June 1998, transfers approximately 2,000 additional depleted UF_6 cylinders from USEC to DOE between 1999 and 2004. (The locations for these cylinders are not specified in this second agreement.)

This chapter provides a brief discussion of the USEC cylinders and the potential environmental impacts that would be associated with their management under each of the alternatives discussed in the PEIS. To account for uncertainties associated with the number of cylinders that would be transferred from USEC to DOE in the future and to provide a bounding analysis of environmental impacts for the purpose of analysis in this PEIS, it was assumed that the number of DOE-owned and DOE-managed cylinders would increase by 15,000 (approximately 180,000 metric tons), with 12,000 of those cylinders being managed at the Paducah site and 3,000 being managed at the Portsmouth site. This assumption is consistent with current operations, under which most or all of the newly generated depleted UF_6 cylinders are at the Paducah site.

6.1 DESCRIPTION OF THE USEC CYLINDER INVENTORY

The USEC-generated cylinders at the Paducah site are located in three storage yards: C-745-C, C-745-Q, and C-745-R (see Figure 3.2). A small number of cylinders are also located for short periods in the C-745-E yard, which is a staging area. The yards used for USEC cylinder storage at the Paducah site had not been paved when the MOAs were signed. Under the terms of the MOAs, yards C-745-Q and C-745-R will be reconstructed with concrete bases, and cylinders from yard C-745-C will then be moved there.

The approximately 2,800 USEC-generated cylinders stored at the Portsmouth site are located in yard X-745-G (see Figure 3.5). This yard has already been paved; however, the cylinders will be restacked onto concrete saddles.

* Please note that this entire chapter has been added to the PEIS after the public comment period.

6.2 APPROACH USED TO EVALUATE THE ENVIRONMENTAL IMPACTS ASSOCIATED WITH MANAGING USEC CYLINDERS

The results from detailed analyses on managing DOE-generated cylinders under various options (presented in Appendices D–J) were used to estimate the potential additional impacts that could result from managing the USEC-generated cylinders as well. In most cases, the impacts for specific management options were estimated by extrapolating from the results presented in Appendices D–J to account for the increase in the cylinder inventory. The activities were then combined to determine the overall impacts associated with each PEIS alternative when both DOE- and USEC-generated cylinders are considered. The specific assumptions that underlie the estimation of impacts for the various components of the alternatives are described here.

6.2.1 Continued Cylinder Storage and Preparation Activities

Management of the USEC-generated cylinders must conform with all requirements applicable to the DOE-generated cylinders. These requirements are described in the UF_6 cylinder project management plan (LMES 1997i). For the site-specific evaluation of continued storage of the USEC-generated cylinders, it was assumed that the USEC cylinders would be managed in the same way as were the DOE-generated cylinders. Management activities would include (1) refurbishment of cylinder yards and restacking as necessary, (2) routine and ultrasonic testing inspections of cylinders and valve monitoring and maintenance, (3) cylinder painting as necessary, and (4) repair and/or removal of the contents of any cylinders that might be breached during the storage period. These activities are described in more detail in Appendix D.

In general, the USEC-generated cylinders are newer than the DOE-generated cylinders and do not exhibit the heavy external corrosion that can result from long-term storage in substandard conditions. Moreover, since these cylinders would be regularly inspected and maintained while under DOE management, future external corrosion would be expected to be minimal. Nonetheless, for the purpose of analyzing continued cylinder storage impacts in this PEIS, the USEC-generated cylinders were assumed to be essentially the same as the DOE-generated cylinders; i.e., the rate of corrosion and the cylinder breach rate were assumed to be the same.

For this PEIS, under the no action alternative, potential environmental impacts were estimated from continued cylinder storage through the year 2039. Under the action alternatives (long-term storage as UF_6, long-term storage as oxide, use as oxide, use as metal, and disposal as oxide), it was assumed that continued cylinder storage would extend from 2009 through 2028 at the current storage sites. The inclusion of the USEC-generated cylinders would increase the length of some continued storage at the Paducah and Portsmouth sites from the year 2028 through about the year 2034. On the basis of the assumption that the rate of cylinder breaches would be the same for the USEC-generated cylinders as for the DOE-generated cylinders, it was estimated that the number of cylinder breaches would increase by 42% at the Paducah site and by 22% at the Portsmouth site. (This increase corresponds directly to the increase in the cylinder inventory at each site.) These assumptions were applied to estimate the number of breaches that would occur in two cases: (1) if painting the cylinders controlled future corrosion and (2) if corrosion continued at the historic rate. For corrosion-induced breaches, these are very conservative assumptions (i.e., are likely to result in overestimates of the number of breaches), because the USEC-generated cylinders are newer than the DOE cylinders.

The other site-specific management option addressed for the PEIS was preparation of cylinders for shipment. As detailed in Appendix E, the number of cylinders that would not meet U.S. Department of Transportation requirements at the time of shipment is unknown. A probable range of values determined by the current cylinder conditions was assumed for the analyses used for Appendix E. To assess the site-specific impacts from the addition of the USEC cylinders, it was assumed that the cylinder preparation options at the Paducah and Portsmouth sites (i.e., preparation of standard cylinders, use of overcontainers, or operation of a cylinder transfer facility) would be extended for about 6 years to accommodate the additional inventory.

Since no USEC-generated cylinders are located at the K-25 site, no impact on continued storage or cylinder preparation at the K-25 site would be associated with the management of the USEC-generated cylinders.

6.2.2 Other Management Options

The additional management options addressed by the PEIS were conversion (including empty cylinder treatment), long-term storage, manufacture and use, and disposal. To account for the management of USEC-generated cylinders for these options, the basic facility designs were assumed to remain the same, but the facilities were assumed to operate over a longer period of time. It was assumed that the period for operations would be extended by about 6 years to accommodate the additional USEC-generated cylinders (i.e., from 20 to 26 years). Under this assumption, annual impacts would generally remain the same as those reported on in Chapter 5 and the appendices, although the total impacts would generally increase by about 30%. Additionally, the land use requirements for the long-term storage and disposal options would be increased to accommodate the additional inventory.

The assumption that operations at these facilities would be extended by 6 years did not change the basic analytical time frame used for the PEIS (i.e., 41 years, from 1998 through 2039). As a result of including the USEC cylinders, the time frame for operations at conversion, long-term storage, manufacture, and disposal facilities was assumed to be from the year 2009 through 2034; monitoring operations at long-term storage facilities were assumed to occur from 2035 through 2039.[1]

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[1] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

6.3 POTENTIAL ENVIRONMENTAL IMPACTS ASSOCIATED WITH MANAGEMENT OF USEC-GENERATED CYLINDERS

The following sections describe the potential environmental impacts associated with the management of USEC-generated cylinders under each of the PEIS alternatives. The potential impacts associated with the increase in the cylinder inventory are discussed relative to the impacts for the management of the DOE-generated inventory only, as presented in Sections 5.1 through 5.7. If the overall impacts would be the same as those presented in Chapter 5, they are generally not discussed in detail in this section; instead, the appropriate sections within Chapter 5 are referenced. If the inclusion of the USEC-generated cylinders would result in changes to the impacts discussed in Chapter 5, the differences are noted and the total impacts are discussed in this section.

6.3.1 No Action Alternative

The inclusion of USEC-generated cylinders under the no action alternative would increase the number of cylinders managed by DOE at the Paducah site by 42% and at the Portsmouth site by 22%. The activities occurring at the K-25 site would be unaffected. The USEC-generated cylinders would be managed in the same manner as would the DOE-generated cylinders, as described in Appendix D.

6.3.1.1 Human Health and Safety

6.3.1.1.1 Normal Facility Operations

In general, the management of USEC-generated cylinders would result in increased levels of exposure to radiation and chemicals by workers and members of the public, when compared with the management of DOE-generated cylinders only as presented in Chapter 5. However, the increased exposure levels would not be large enough to cause appreciable increases in the potential health impacts under the no action alternative discussed in Chapter 5.

Workers. In general, the management of USEC-generated cylinders would increase the overall level of activity of involved workers by approximately 30%, resulting in a corresponding increase in the total radiation dose to the worker population over the duration of the program. It is estimated that the total dose to involved workers at all three sites would increase from about 1,500 to about 2,000 person-rem. (The dose to noninvolved workers would remain negligible when compared with the involved worker dose.) However, this increase in the radiation dose would not change the estimate of 1 LCF among workers under the no action alternative.

In addition, the average annual radiation dose to individual workers associated with management of the additional USEC-generated cylinders would be the same as that reported for the management of DOE-generated cylinders only, because additional cylinder yard workers would be used to perform the necessary activities instead of having the same individuals conduct extra activities. Thus, the number of involved workers at the Paducah site would increase from about 30 to 43 and the number at Portsmouth would increase from about 16 to 20. The average annual doses to involved workers would remain at about 740 mrem/yr at Paducah and 600 mrem/yr at Portsmouth, well within applicable standards.

General Public. The management of USEC-generated cylinders would result in a potential increase in the total radiation dose to the public from airborne releases that would be proportional to the increase in the total cylinder inventory and number of hypothetical cylinder breaches (i.e., by approximately 30%). Therefore, it is estimated that the total radiation dose to the general public within 50 mi (80 km) of the three current storage sites combined would increase by 0.11 person-rem, resulting in a total dose of 0.49 person-rem over the duration of the program. This level of exposure would remain well below levels expected to cause any adverse health effects.

The maximum radiation dose to an individual near the Paducah and Portsmouth sites would also increase because of the additional management of USEC-generated cylinders. However, this increase would be such that the dose to an individual near any one of the three storage sites would be less than 0.2 mrem/yr, the same as the dose for DOE-generated cylinders only reported on in Chapter 5. Similarly, the change in the potential for noncancer health effects from exposure to airborne uranium and HF releases would be such that the maximum hazard index for an individual would remain less than 0.1, as reported on in Section 5.1.1.1.2.

The estimated maximum uranium concentrations in groundwater and resulting health effects among members of the public from future cylinder breaches would be the same as those for the management of DOE-generated cylinders discussed in Chapter 5. The reason is that the estimated groundwater concentrations for the DOE-generated cylinders were calculated on the basis of hypothetical breaches occurring in the G-yard at the Paducah site and in both the C-yard and E-yard at the Portsmouth site. This assumption represents a worst-case scenario in terms of groundwater contamination; additional breaches from USEC cylinders stored in different yards would not increase the estimated groundwater concentrations. Therefore, the radiation dose and hazard index estimates given in Section 5.1.1.1.2 for the general public from use of contaminated groundwater under the no action alternative would not change as a result of the additional consideration of the USEC cylinders.

6.3.1.1.2 Facility Accidents

Physical Hazards (On-the-Job Injuries and Fatalities). The activities associated with managing and handling the USEC cylinders would be the same as those required for the DOE-generated cylinders. The number of additional accidental worker injuries and fatalities associated with maintenance and handling of the USEC-generated cylinders at the Paducah and Portsmouth sites would be about 40 injuries and 0.03 fatality through 2039.

The total number of accidental worker fatalities and injuries at the three sites through 2039 under the no action alternative would increase by about 30%. The number of fatalities, when both DOE- and USEC-generated cylinders are considered, would be 0.14, well below 1. The estimated total number of accidental worker injuries would be 182.

Accidents Involving Releases of Radiation or Chemicals. For accident consequences, impacts would be the same as those for the DOE-generated cylinders under the no action alternative discussed in Section 5.1.1.2.2, because the types of accidents assessed would involve only a limited amount of material that would be at risk under accident conditions, regardless of the number of cylinders in storage. (For example, a vehicle-induced fire would be estimated to involve three full cylinders, regardless of the number of cylinders at the sites.) Although the estimated frequencies of some accidents would increase somewhat in association with the management of the additional USEC-generated cylinders (e.g., cylinder handling accidents), this increase would not be expected to be enough to change the overall expected frequency of specific accidents from the broad ranges used for this PEIS (i.e., likely is defined as one time or more in 100 years; unlikely is one time between 100 years and 10,000 years; extremely unlikely is one time between 10,000 years and 1 million years; incredible is less than one time in 1 million years).

6.3.1.2 Transportation

The continued storage of the USEC-generated cylinders under the no action alternative would result in small, additional quantities of LLW and LLMW (from cylinder monitoring and maintenance activities) that would need to be shipped each year. This additional waste would result in less than one additional waste shipment each year. Because of the small number of shipments and the low concentrations of contaminants expected, the potential environmental impacts from these shipments would remain negligible.

6.3.1.3 Air Quality

Continued storage of the USEC-generated cylinders would require refurbishment of the storage yards used for these cylinders. The paving of these yards would result in particulate matter (PM_{10}) emissions (i.e., dust). For the continued storage of DOE-generated cylinders, as described in Section 5.1.3, potential PM_{10} emissions during construction activities would approach regulatory standards. This situation would also occur during refurbishment of the yards used for USEC cylinder storage. Emissions would be expected to be less than or equal to those estimated for the DOE-generated cylinders, because refurbishment of cylinder yards would be conducted sequentially and the yards being used to store USEC-generated cylinders and requiring refurbishment would be approximately the same size and in the same general location as the yards being used for DOE-generated cylinder storage. Mitigative measures, such as water spraying, might be required to reduce the PM_{10} emissions during refurbishment of cylinder yards for both the DOE- and USEC-generated cylinders.

The overall site emissions of criteria pollutants would increase as a result of the continued storage of USEC cylinders; however, the resulting concentrations would remain well below regulatory standards. Painting the USEC-generated cylinders to protect them from external corrosion, as needed, would also not have a significant impact on regional ozone formation.

Under the no action alternative, potential emissions of HF due to hypothetical breaches of some USEC-generated cylinders were estimated to remain well within applicable standards and guidelines at the Paducah and Portsmouth sites, whether or not corrosion control was assumed.

6.3.1.4 Water and Soil

Construction activities associated with refurbishment of USEC storage yards would be limited and occur in previously developed areas; therefore, impacts in assessment areas, such as changes in runoff, recharge to underlying aquifers, and changes in soil permeability or erosion potential, would be expected to be very minimal. Additional water use for continued storage of USEC-generated cylinders was roughly estimated to be 0.8 million gal for construction at the Paducah site, 67,000 gal/yr for operations at the Paducah site, and 13,000 gal/yr for operations at the Portsmouth site. Total water use would be 3 million gal for construction, 230,000 gal/yr for operations at Paducah, and 73,000 gal/yr for operations at Portsmouth.

Releases from hypothetical breaches of the USEC cylinders would, in general, increase concentrations in groundwater in some areas of the sites (i.e., in the areas near or in USEC cylinder storage yards). However, maximum concentrations calculated for evaluating the worst-case impacts to groundwater at the Paducah site (G-yard) and the Portsmouth site (combined C- and E-yards) under the no action alternative would remain the same as those described in Section 5.1.4.2. These concentrations would not change because the number of cylinders at the G-yard and the combined C- and E-yards would be the same (USEC cylinders would be stored at other yards) and because, in the groundwater modeling method used, contaminant plumes emanating from the vicinity of the yards are assumed to be independent and to not interact because of the distance separating the yards, the short travel distance to the assumed receptor (i.e., 1,000 ft), and limited plume spreading caused by lateral dispersion. Therefore, although concentrations of uranium in groundwater beneath some cylinder storage yards would increase because of the addition of the USEC cylinders, the maximum concentrations for the entire site would still be represented by the values given in Section 5.1.4.2 (i.e., 6 and 5 μg/L for the Paducah and Portsmouth sites, respectively).

Maximum concentrations in surface water bodies adjacent to the two sites would also stay about the same (0.3 μg/L at Paducah and 0.7 μg/L at Portsmouth) because of dilution in these water bodies. For soil, worst-case concentrations would remain the same (about 1 μg/g at either site); runoff from the USEC yards would not mix with runoff from the G-yard at Paducah or combined C- and E-yards at Portsmouth to increase local soil contaminant concentrations.

6.3.1.5 Socioeconomics

Additional construction activities that would result from the addition of USEC-generated cylinders at the Paducah site would generate approximately 8 additional direct jobs and about 34 additional total jobs. Operational activities at both the Paducah and Portsmouth sites would create 29 additional direct jobs and 45 additional total jobs per year. Direct additional income from construction at the Paducah site in the peak year would be $0.42 million, and total additional income would be $0.84 million. During operations, additional direct and total income at both the Paducah and Portsmouth sites would be $0.9 million and $1.2 million per year, respectively.

The additional employment and income created in the ROIs for the two sites would represent a very small change (estimated as less than 0.002%) in projected growth in these indicators of overall regional activity. The in-migration expected into each region with each activity would have only a low impact on regional population growth rates and would require less than 0.8% of vacant housing stock at either of the two sites. No significant impacts on local public finances would be expected.

The total socioeconomic impacts under the no action alternative (when both DOE- and USEC-generated cylinders are considered) would be 38 direct jobs and 174 total jobs in the peak construction year, 140 direct jobs and 255 total jobs per year during operations, $1.8 million direct income and $4.3 million total income from construction, and $6 million/yr direct income and $7.9 million/yr total income during operations. These values represent a total change of less than 0.007% of projected growth. A total of less than 3% of vacant housing stock at any of the sites would be required.

6.3.1.6 Ecology

Impacts to ecological resources from the continued storage of the additional USEC-generated cylinders would be minimal. Concentrations of uranium in soil, groundwater, and surface water would remain well below benchmark values for toxic and radiological effects. (Benchmarks are given in Section C.3.3.) In addition, construction activities would take place on previously disturbed areas (i.e., existing yards) and would have no ecological impacts.

6.3.1.7 Waste Management

Painting the USEC-generated cylinders at the Paducah site would add a maximum of an additional 8% to the site's total annual LLMW load (added to the 20% projected from painting the DOE-generated cylinders). Painting at the Portsmouth site would not significantly increase the 1% proportion of LLMW generation at the site that would be attributable to the DOE-generated cylinders only. The continued storage of the USEC-generated cylinders together with the DOE-generated cylinders would thus constitute a moderate potential impact on LLMW management at the Paducah site. The total impact on the projected annual DOE LLMW treatment volume, however, would be negligible to low.

6.3.1.8 Resource Requirements

Although the total resources required would increase by approximately 30% as a result of the inclusion of USEC-generated cylinders, continued storage activities would not be resource intensive, and no strategic or critical materials would be required. The continued storage of the DOE- and USEC-generated cylinders would have a negligible to low impact on resource requirements at the Paducah and Portsmouth sites.

6.3.1.9 Land Use

The cylinder yards that are or would be used to store USEC-generated cylinders have either already been used as cylinder yards or would be located in previously developed areas and thus would not impact land use at the Paducah or Portsmouth sites under the no action alternative.

6.3.1.10 Cultural Resources

The yards for USEC-generated cylinders at the Paducah and Portsmouth sites are located in previously disturbed areas unlikely to contain cultural properties or resources listed on or eligible for the National Register of Historic Places. Therefore, impacts to cultural resources would not be likely under the no action alternative.

6.3.1.11 Environmental Justice

No disproportionately high and adverse effects to minority or low-income populations would be expected in the vicinity of the Paducah and Portsmouth sites in association with the continued storage of the USEC-generated cylinders.

6.3.2 Long-Term Storage as UF_6

Under the long-term storage as UF_6 alternative, the inclusion of USEC-generated cylinders would increase the number of cylinders managed by DOE at the Paducah site by 42% and at the Portsmouth site by 22%. Activities at the K-25 site would be unaffected. Consequently, the duration of continued cylinder storage at the Paducah and Portsmouth sites would be extended by about 6 years, from 2028 to 2034. In addition, the number of cylinder shipments to a consolidated storage facility would increase by about 30%. The operational and construction (or emplacement) period for a consolidated long-term storage facility would be extended from 20 to 26 years, with approximately 30% more area being required for storage at the facility. At a long-term storage facility, surveillance and maintenance requirements would increase during the additional years of emplacement, for a total increase of 30% for the surveillance and maintenance period of 2035 through 2039.

6.3.2.1 Human Health and Safety

6.3.2.1.1 Normal Facility Operations

In general, the management of USEC-generated cylinders would increase the level of exposure of workers and members of the public to radiation and chemicals when compared with the management of DOE-generated cylinders only as presented in Section 5.2.1.1. For involved workers, the increased radiation exposure could result in 1 LCF in addition to the potential 1 LCF estimated for the management of DOE-generated cylinders. (The estimated number of LCFs increases by one because of rounding effects and the fact that estimates are presented as a single whole number.) For noninvolved workers and members of the public, the increased levels of exposure would not be large enough to cause appreciable increases in the potential health impacts over those under the long-term storage as UF_6 alternative discussed in Chapter 5.

Workers. Under the long-term storage as UF_6 alternative, the management of the additional USEC cylinders (including continued cylinder storage, cylinder treatment, and consolidated storage) was estimated to increase the total dose to involved workers by about 30%, resulting in 1 additional LCF under each of the three long-term storage options (yards, buildings, and mines). The total number of health effects among involved workers (including both DOE- and USEC-generated cylinders) would be about 1 to 2 LCFs over the duration of the program. (The dose to noninvolved workers would remain negligible when compared with the involved worker dose.)

In general, the average annual radiation dose to individual workers associated with management of the additional USEC cylinders would be the same as that reported on in Chapter 5 for DOE-generated cylinders (i.e., well within applicable standards) because additional workers would be used instead of having the same individuals conduct extra activities at both the current storage sites and a long-term storage facility.

Increased exposure to chemicals would not be expected to increase health impacts among involved or noninvolved workers. The total estimated hazard indices (when both DOE- and USEC-generated cylinders are considered) would be less than 0.002 for noninvolved workers at all three sites and at a consolidated storage facility.

General Public. The management of USEC-generated cylinders would result in a potential increase in the total radiation dose to the public around the three current storage sites from airborne releases. The increase would be proportional to the increase in the total cylinder inventory and number of hypothetical cylinder breaches (i.e., approximately 30%). Therefore, it was estimated that the total radiation dose to the general public within 50 mi (80 km) of the three current storage sites combined would increase by about 0.3 person-rem, resulting in a total dose of 1.4 person-rem over the period 1999 through 2034. This level of exposure would remain well below levels expected to cause any adverse health effects.

The maximum radiation dose to an individual near the Paducah and Portsmouth sites would also increase because of the additional management of USEC-generated cylinders. However, this increase would be such that the dose to an individual near any one of the three storage sites would be less than 0.2 mrem/yr, the same as the dose reported on for DOE-generated cylinders only in Chapter 5. Similarly, the change in the potential for noncancer health effects from exposure to airborne uranium and HF releases would be such that the maximum hazard index for an individual would remain less than 0.1, as it would be for the long-term storage as UF_6 alternative reported on in Section 5.2.1.1.2.

Potential health impacts from surface and groundwater contamination associated with the management of the USEC-generated cylinders would be the same as those for DOE-generated cylinders discussed in Section 5.2.1.1.2. This result would occur because the modeling of releases to groundwater at the Paducah and Portsmouth sites for the DOE-generated cylinders represents a worst-case scenario; additional breaches from USEC cylinders stored in different yards would not increase the estimated groundwater concentrations under either cylinder corrosion assumption (controlled corrosion or uncontrolled cylinder corrosion).

For the reasons discussed for DOE-generated cylinders in Chapter 5, impacts to members of the general public near a consolidated storage facility would be less than or equal to those presented for the three current storage sites: no health effects would be expected.

6.3.2.1.2 Facility Accidents

Physical Hazards (On-the Job Injuries and Fatalities). For the long-term storage as UF_6 alternative, it was estimated that up to 1 additional worker fatality and up to 240 additional worker injuries could occur in association with management of the USEC-generated cylinders (including continued storage, cylinder preparation, and long-term storage as UF_6). The total physical hazards associated with management of the DOE- and USEC-generated cylinders would be about 2 worker fatalities and up to 1,200 worker injuries, an increase of roughly 30%.

Accidents Involving Releases of Radiation or Chemicals. For accident consequences, impacts would be the same as those for the DOE-generated cylinders under the long-term storage as UF_6 alternative discussed in Section 5.2.1.2.2. Although the estimated frequencies of some accidents would increase somewhat in association with the management of the additional USEC cylinders, this increase would not be expected to be enough to change the overall expected frequency of specific accidents from the broad ranges used for this PEIS.

6.3.2.2 Transportation

The management of USEC-generated cylinders would result in an additional 15,000 truck shipments of UF_6 cylinders from the current storage sites to a consolidated long-term storage site, or an additional 3,750 rail shipments. (The annual number of shipments would be the same as that for DOE-generated cylinders described in Section 5.2.2 and Appendix J.) For normal (incident-free) transportation operations, these additional shipments would increase exposure to overall external radiation and vehicle exhaust emissions by about 30%. However, no adverse health effects would be expected among workers and the public during normal transportation activities when shipment of both DOE- and USEC-generated cylinders is considered.

Although the total number of shipments would increase by about 30%, the estimated number of fatalities from transportation accidents (not involving releases of radioactive or hazardous materials) would be the same as that for DOE-generated cylinders reported on in Section 5.2.2. (The estimated number of traffic fatalities would not change because of rounding effects and the fact that estimates are presented as a single whole number.) Thus, the total estimated number of traffic accident fatalities under the long-term storage as UF_6 alternative (including both DOE- and USEC-generated cylinders) would remain 2 for truck transport and 1 for rail transport.

The consequences of severe traffic accidents involving releases of radiation or chemicals would be the same as those for the shipment of DOE-generated cylinders described in Section 5.2.2, because the shipment sizes would not change. The annual probability of severe accidents occurring would be the same as that discussed for DOE-generated cylinders, although the total probability of a severe accident would increase by about 30% as shipments continued for an additional 6 years.

6.3.2.3 Air Quality

The continued storage of additional USEC cylinders at the Paducah and Portsmouth sites through the year 2034 would not result in significant impacts to air quality. The estimated concentrations of criteria pollutants at the current storage sites would remain approximately the same as those for the long-term storage as UF_6 alternative, when only DOE-generated cylinders are considered, as described in Section 5.2.3. The estimated maximum 24-hour average HF concentrations at the Paducah and Portsmouth sites would increase from about 0.22 $\mu g/m^3$ and 0.14 $\mu g/m^3$ to about 1.2 $\mu g/m^3$ and 0.44 $\mu g/m^3$, respectively. The overall concentration for the Paducah site would still be well below the Kentucky primary 24-hour standard for HF of 800 $\mu g/m^3$. The State of Ohio does not have air standards for HF.

At a consolidated long-term storage facility, impacts on criteria pollutant emissions from construction and operation would be the same as those for DOE-generated cylinders discussed in Section 5.2.3. The air quality impacts would be the same because, although the size of the long-term storage facility would increase by about 30% as a result of the addition of the USEC-generated cylinders, the annual level of operations (and emissions) would remain unchanged. No emission of uranium compounds was predicted in association with consolidated storage as UF_6.

6.3.2.4 Water and Soil

At the current storage sites, additional water use for continued storage of USEC-generated cylinders was roughly estimated to be 0.8 million gal for construction at the Paducah site, 67,000 gal/yr for operations at the Paducah site, and 13,000 gal/yr for operations at the Portsmouth site. The estimated total water use would be about 3 million gal for construction, 230,000 gal/yr during operations at Paducah, and 73,000 gal/yr for operations at Portsmouth.

The annual water requirements for a cylinder transfer facility would not change from those presented in Section 5.2.4 (i.e., between 6 and 9 million gal/yr), because the size of the facility would not change. However, the facility would be operated for an additional 6 years.

Because the duration of construction and operational activities at a long-term storage facility would be increased by 6 years, from 3.0 to 38 million gal of additional water would be required for construction, and about 7 million gal of additional water would be required for operations. About 6.6 million gal of additional wastewater would be generated. The total amount of water required during construction would be about 13 to 170 million gal; the total amount of water used during operations would be about 31 million gal; the total wastewater generated would be about 29 million gal.

As discussed in Section 6.3.1.4, the overall impacts to surface water, groundwater, and soil from the continued storage of USEC cylinders under this alternative would be the same as those estimated for the DOE-generated cylinders in Section 5.2.4. The estimated maximum groundwater uranium concentrations from continued storage at the Paducah and Portsmouth sites (i.e., 20 μg/L and 4 μg/L, respectively) would not change as a result of considering the USEC cylinders. Potential groundwater impacts would be mitigated by collecting and treating runoff from the cylinder yards and by identifying and repairing breached cylinders as soon as possible. The estimated maximum soil uranium concentration would remain 7 μg/g, well within the 230-μg/g guideline used for comparison.

Because total overall discharges would be extremely small, no impacts to groundwater quality would be expected from cylinder preparation activities or at a consolidated long-term storage facility.

The addition of USEC-generated cylinders would increase requirements for excavating a mine for a long-term storage facility. The additional excavation volume would be about 300,000 yd^3 (230,000 m^3). The total required excavation volume for the mine would be about 2.1 million yd^3 (1.6 million m^3).

6.3.2.5 Socioeconomics

Under the long-term storage as UF_6 alternative, continued storage of the additional USEC-generated cylinders would result in about 8 additional direct construction jobs and about 34 additional total jobs at the Paducah site. Operational activities at both the Paducah and Portsmouth sites would create 29 additional direct jobs and 45 additional total jobs per year. Additional direct and total income from construction at the Paducah site in the peak year would be $0.42 million and $0.84 million, respectively. During operations, additional direct and total income at both the Paducah and Portsmouth sites would be $0.8 million/yr and $1 million/yr, respectively.

The total socioeconomic impacts for continued cylinder storage under the long-term storage as UF_6 alternative (including both DOE- and USEC-generated cylinders) would be 38 direct jobs and 174 total jobs in the peak construction year, 150 direct jobs and 275 total jobs per year during operations, $1.8 million direct income and $4.3 million total income from construction, and $6.8 million/yr direct income and $8.9 million/yr total income during operations.

The annual socioeconomic impacts from cylinder preparation activities would be the same as those for the DOE-generated cylinders only estimated in Section 5.2.5, but the period of operation would be extended by 6 years. Construction impacts would not change for the cylinder preparation options because facility sizes would remain the same.

Construction and operation of a long-term storage facility would be extended by 6 years as a result of the addition of the USEC-generated cylinders. The peak year construction costs would not change. For operations, the emplacement period, originally assumed to extend from the year 2009 through 2028, would be extended through 2034, with the surveillance and maintenance period being reduced to the years 2035 through 2039. The average annual income and number of jobs estimated for the surveillance and maintenance period would increase by about 30% as a result of the addition of the USEC-generated cylinders. To estimate the change in socioeconomic impacts associated with the additional USEC cylinders, 30% of the average annual number of jobs and income during the surveillance and maintenance period for each option were added to the average annual number of jobs and income during the emplacement period from 2009 through 2028 (Allison and Folga 1997). Adding this increased the range for the number of annual jobs by 11–14 for the long-term storage as UF_6 options, resulting in a total range of 60 to 70 jobs when both DOE- and USEC-generated cylinders are considered. Correspondingly, annual income would increase by about $1 million, to a total of $4 million.

6.3.2.6 Ecology

The continued storage and preparation of the USEC-generated cylinders at the current storage sites would not result in additional impacts to ecological resources. Concentrations of uranium in soil, groundwater, and surface water would remain well below benchmark values for toxic and radiological effects (see Section C.3.3). In addition, construction activities would take place on previously disturbed areas (i.e., existing yards) and would have no ecological impacts.

The storage of the USEC-generated cylinders at consolidated long-term storage facilities would increase land use requirements by 11 to 26 acres (4 to 10 ha), which would result in additional habitat loss. The total land required would range from 107 to 170 acres (43 to 68 ha), which could have a large impact on vegetation and wildlife.

6.3.2.7 Waste Management

Continued storage of USEC-generated cylinders under the long-term storage as UF_6 alternative would increase waste impacts at the current storage sites. The maximum additional impacts from management of the USEC-generated cylinders at the Paducah site would be the same as those under the no action alternative discussed in Section 6.3.1.7. Because the annual treatment volumes would not change, operational impacts related to waste handling would not be impacted (see Section 5.2.7). However, the timeframe of operations would increase by 6 years, and the total amount of waste generated would increase by about 30%.

For the operation and construction of a consolidated long-term storage facility, the addition of the USEC cylinders would generate an additional 900 yd^3 (690 m^3) of LLW and 240 yd^3 (180 m^3) of LLMW for storage in yards and about 25 yd^3 (19 m^3) of LLW for storage in buildings or a mine. The total waste generated would be about 3,700 yd^3 (2,800 m^3) of LLW and 970 yd^3 (740 m^3) of LLMW for storage in yards and 100 yd^3 (80 m^3) of LLW for storage in buildings or a mine.

The generation of waste under the long-term storage as UF_6 alternative (when both DOE- and USEC-generated cylinders are considered) would have a negligible to low impact when considered in terms of national and regional waste management capabilities. That is, the required increase in capacity at the regional and national level would be less than 10%.

6.3.2.8 Resource Requirements

In general, the addition of the USEC cylinders would not change the assessment of impacts on resource requirements for DOE-generated cylinders presented in Chapter 5 (i.e., no significant impacts would result because construction and operational requirements would not be resource intensive, and the resources required would not be rare or unique). The electrical requirement for mine construction would increase by about 130 MW-yr to a total of 970 MW-yr. The impact of this high electrical requirement on use of local energy resources would depend on the location of the facility and the existing infrastructure.

6.3.2.9 Land Use

At the current storage sites, the impacts to land use from the addition of USEC-generated cylinders would be the same as that for management of DOE-generated cylinders described in Section 5.2.9. Storage space for the USEC cylinders is already present at the sites. If transfer facilities were built for cylinder preparation, the land use requirements would be the same as those for the DOE-generated cylinders only described in Section 5.2.9, because the facility operational period would increase, not the facility size.

The increase in land use requirements at long-term storage facilities to accommodate the USEC-generated cylinders would range from 11 to 26 acres (4 to 10 ha). The total land use requirement for long-term storage of DOE- and USEC-generated cylinders would range from 107 to 170 acres (43 to 68 ha), constituting a moderate potential land use impact.

6.3.2.10 Cultural Resources

The potential impacts to cultural resources would be the same as those for the DOE-generated cylinders under the long-term storage as UF_6 alternative discussed in Section 5.2.10: impacts to cultural resources would be unlikely at the current storage sites because all activities would take place on previously developed land, and cultural impacts at a long-term storage facility would depend on the location of the facility.

6.3.2.11 Environmental Justice

The impacts to environmental justice would be the same as those for the DOE-generated cylinders under the long-term storage as UF_6 alternative discussed in Section 5.2.11. No disproportionately high and adverse effects to minority or low-income populations would be expected in the vicinity of the Paducah and Portsmouth sites in association with the continued cylinder storage and/or cylinder preparation under the long-term storage as UF_6 alternative.

6.3.3 Long-Term Storage as Uranium Oxide

Under the long-term storage as oxide alternative, the inclusion of USEC-generated cylinders would increase the number of cylinders managed by DOE at the Paducah site by 42% and at the Portsmouth site by 22%. Activities occurring at the K-25 site would be unaffected. Consequently, the duration of continued cylinder storage at the Paducah and Portsmouth sites would be extended by about 6 years, from 2028 to 2034. In addition, the total number of shipments of cylinders, uranium oxide, HF, and associated materials would increase by about 30%, although the annual number of shipments would be unchanged. The operational period for a conversion facility would be extended from 20 to 26 years to accommodate the additional processing of USEC-generated cylinders. Similarly, the operational and construction (or emplacement) period for a long-term storage facility would also be increased from 20 to 26 years, with approximately 30% more land area being required for storage at the facility. At a long-term storage facility, surveillance and maintenance requirements would increase during the additional 6 years of emplacement, for a total increase of 30% for the surveillance and maintenance period of 2035 through 2039.

6.3.3.1 Human Health and Safety

6.3.3.1.1 Normal Facility Operations

For the long-term storage as oxide alternative, the management of USEC-generated cylinders would increase the level of exposure of workers and members of the public to radiation and chemicals, when compared with the management of DOE-generated cylinders only as presented in Chapter 5. For involved workers, the increased radiation exposure could result in a maximum of 1 LCF in addition to the potential 1 to 2 LCFs estimated for the management of DOE-generated cylinders. (The estimated total, when both DOE- and USEC-generated cylinders are considered, would be 1 to 3 LCFs.) For noninvolved workers and members of the public, the increased levels of exposure would not be large enough to cause appreciable increases in the potential health impacts over those under the long-term storage as oxide alternative discussed in Chapter 5.

Workers. Under the long-term storage as oxide alternative, the management of the additional USEC cylinders (including continued cylinder storage, cylinder preparation, conversion, empty cylinder treatment, and consolidated storage of oxide) was estimated to increase the total dose to involved workers by about 30%, resulting in a maximum of 1 additional LCF under each of the three long-term storage options (buildings, vaults, and mines). The total number of health effects among involved workers (when both DOE- and USEC-generated cylinders are considered) would range from 1 to 3 LCFs over the duration of the program. (The dose to noninvolved workers would remain negligible when compared with the involved worker dose.)

In general, the average annual radiation dose to individual workers associated with management of the additional USEC cylinders would be the same as that for DOE-generated cylinders reported on in Chapter 5 (i.e., well within applicable standards) because (1) at the current storage sites and a long-term storage facility, additional workers would be used instead of having the same individuals conduct extra activities, and (2) at conversion facilities, the annual worker activities would be the same, but the facilities would operate over a longer period of time.

Increased exposure to chemicals would not be expected to increase health impacts on involved or noninvolved workers; the total estimated hazard indices (when both DOE- and USEC-generated cylinders are considered) would be less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, or a consolidated long-term storage facility.

General Public. The overall potential impacts to members of the general public during normal operations would be the same as those for the management of DOE-generated cylinders described in Section 5.3.1.1.2: all exposures would be within applicable public health standards, and no LCFs from radiation exposures and no adverse effects from chemical exposures would be expected to occur among members of the general public near the three current storage sites, a conversion facility, or a consolidated long-term storage facility, when the management of additional USEC cylinders is considered.

At the current storage sites, potential public exposure to radiation and chemicals released from the sites would be exactly the same as that under the long-term storage as UF_6 alternative described in Section 6.3.2.1.1.

At conversion and long-term storage facilities, the annual impacts to members of the public would be the same as those for management of DOE-generated cylinders described in Section 5.3.1.1.2, because the annual operations would be the same. The total exposure of the public in the vicinity of these facilities to airborne radiation and chemicals would increase by approximately 30% as a result of the processing of USEC-generated cylinders. However, total exposure levels would remain well within standards and below levels expected to cause any adverse health effects among the public for all storage options.

6.3.3.1.2 Facility Accidents

Physical Hazards (On-the Job Injuries and Fatalities). For the long-term storage as oxide alternative, it was estimated that 1 additional worker fatality and up to 460 additional worker injuries could occur in association with management of the USEC-generated cylinders (including continued storage, cylinder preparation, empty cylinder treatment, conversion to oxide, and long-term storage as oxide activities). The total physical hazards associated with management of the DOE- and USEC-generated cylinders would range from about 1 to 3 worker fatalities and about 900 to 2,100 worker injuries.

Accidents Involving Releases of Radiation or Chemicals. For accident consequences, impacts would be the same as those for the DOE-generated cylinders under the long-term storage as oxide alternative discussed in Section 5.3.1.2.2. Although the estimated frequencies of some accidents would increase somewhat in association with the management of the additional USEC cylinders, this increase would not be expected to be enough to change the overall expected frequency of specific accidents from the broad ranges used for this PEIS.

6.3.3.2 Transportation

The management of the USEC-generated cylinders would result in an increase of approximately 30% in the total number of shipments of UF_6 cylinders, uranium oxide, ammonia, anhydrous HF (if produced), CaF_2 (if produced), and waste materials. (The annual number of shipments would be the same as that for DOE-generated cylinders described in Section 5.3.2 and Appendix J.) For normal (incident-free) transportation operations, these additional shipments would increase exposure to overall external radiation and vehicle exhaust emissions by about 30%. However, no adverse health effects would be expected among workers and the public during normal transportation activities when shipment of both DOE- and USEC-generated cylinders and associated materials is considered.

Although the total number of shipments would increase by about 30%, the estimated number of fatalities from transportation accidents (not involving releases of radioactive or hazardous materials) would be the same as that for DOE-generated cylinders described in Section 5.3.2. As described under the long-term storage as UF_6 alternative in Section 6.3.2.2, the estimated number of traffic fatalities would not change because of rounding effects and the fact that estimates are presented as a single whole number. Thus, the total estimated number of traffic accident fatalities under the long-term storage as oxide alternative (when both DOE- and USEC-generated cylinders are considered) would remain 4 for truck transport and 2 for rail transport.

The consequences of severe traffic accidents involving releases of radiation or chemicals would be the same as those for the shipment of DOE-generated cylinders and associated materials described in Section 5.3.2, because the shipment sizes would not change. The annual probability of severe accidents occurring also would be the same as that discussed in Section 5.3.2, although the total probability of a severe accident would increase by about 30% as shipments continued for an additional 6 years.

6.3.3.3 Air Quality

At the current storage sites, air quality impacts would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.3.

At a conversion to oxide facility, annual criteria pollutant emissions from construction and operation would be identical to those discussed for DOE-generated cylinders in Section 5.3.3, because conversion facilities would not increase in size, only in duration of operations. During an additional 6 years of operation, an additional 12 to 66 lb (5 to 30 kg) of uranium (as U_3O_8 or UO_2) would be emitted. The total uranium emissions that would result from conversion of both the DOE- and USEC-generated inventory could range from about 52 to 290 lb (24 to 132 kg). No air quality standards exist for uranium compounds. However, the potential health impacts from these emissions were evaluated in Section 6.3.3.1.1.

At a long-term storage facility, although the size of the facility would increase, annual average air concentrations of criteria pollutants and other emissions would remain the same as those predicted for the DOE-generated cylinders only in Section 5.3.3. No emission of uranium compounds is predicted in association with the long-term storage as oxide facility.

6.3.3.4 Water and Soil

At the current storage sites, impacts to surface water, groundwater, and soil would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.4.

The amount of water used to construct a conversion facility would be the same as that for DOE-generated cylinders described in Section 5.3.4. The duration of operational activities at a conversion facility would increase by 6 years; resulting in an additional water requirement of about 200 to 1,700 million gal. From about 90 to 840 million gal of additional wastewater would be generated over the additional 6 years of operation. The total water requirement at a conversion facility would range from about 880 to 7,400 million gal; the total wastewater generated would range from about 390 to 3,600 million gal.

The duration of both construction and operational activities at a long-term storage facility would increase by 6 years, so about 2 to 8 million gal of additional water would be required for construction, and about 8 million gal of additional water would be required for operations. Additional wastewater generation would range from about 0.6 to 8 million gal. The total water requirement for construction would range from 8 to 34 million gal; the total water requirement for operations would be about 36 million gal. Total wastewater generation would range from about 3 to 36 million gal.

Impacts to surface water and groundwater from an oxide conversion facility or a long-term storage facility would depend on the actual location of the facility. On the basis of an assessment of representative settings considered for this PEIS, impacts from the DOE cylinders only were expected to be negligible, as described in Section 5.3.4.1. Additional impacts to surface water and groundwater as a result of the additional USEC-generated cylinders during conversion to oxide and long-term storage would also probably be negligible because annual emissions would not change.

The conversion and storage of USEC-generated cylinders would increase requirements for excavating a mine for a long-term storage facility. The additional excavation volume would be about 400,000 yd^3 (306,000 m^3) for storage as U_3O_8 in a mine and 200,000 yd^3 (150,000 m^3) for storage as UO_2 in a mine. The maximum total required excavation volume for a mine would be about 2.6 million yd^3 (2.0 million m^3).

6.3.3.5 Socioeconomics

At the current storage sites, socioeconomic impacts would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.5.

The annual socioeconomic impacts from operating a conversion to oxide facility would be the same as those estimated for the DOE-generated cylinders in Section 5.3.5, but the period of operation would be extended by 6 years. Annual socioeconomic impacts during construction would also be the same as those for managing DOE-generated cylinders, but the period of construction activities for the long-term storage facility would also be extended by 6 years.

Construction and operation of a long-term storage as oxide facility would be extended by 6 years as a result of the addition of the USEC-generated cylinders. The peak year construction costs would not change. For operations, the emplacement period, originally assumed to extend from the year 2009 through 2028, would be extended through 2034, with the surveillance and maintenance period being reduced to the years 2035 through 2039. The average annual income and number of jobs estimated for the surveillance and maintenance period would increase by about 30% as a result of the addition of the USEC-generated cylinders. To estimate the change in socioeconomic impacts associated with the additional USEC cylinders, 30% of the average annual number of jobs and income during the surveillance and maintenance period for each option were added to the average annual number of jobs and income during the emplacement period from 2009 through 2028 (Allison and Folga 1997). Adding this increased the range for the number of annual jobs by 12–15 for the long-term storage as oxide options, resulting in a total range of 70 to 80 jobs when both DOE- and USEC-generated cylinders are considered. Correspondingly, annual income would increase by about $1 million, to a range of $4–5 million.

6.3.3.6 Ecology

The continued cylinder storage and preparation activities associated with management of the USEC-generated cylinders at the current storage sites would not result in additional impacts to ecological resources. Concentrations of uranium in soil, groundwater, and surface water would remain well below benchmark values for toxic and radiological effects (see Section C.3.3). In addition, construction activities would take place on previously disturbed areas (i.e., existing yards) and would have no ecological impacts.

At a conversion facility, treatment of USEC-generated cylinders would not result in any additional land use requirements or habitat loss, because the size of the conversion facility would not change. At a long-term storage facility, storage as U_3O_8 would increase land use from 14 to 52 acres (6 to 21 ha). Storage as UO_2 would increase land use from 7 to 22 acres (3 to 9 ha). These increases would result in additional habitat loss. The total land required for long-term storage would range from 135 to 264 acres (54 to 106 ha) for storage as U_3O_8, and from 81 to 135 acres (32 to 54 ha) for storage as UO_2. These total land requirements would have a moderate to large potential impact on vegetation and wildlife.

6.3.3.7 Waste Management

At the current storage sites, waste management impacts would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.7.

The duration of operational activities at a U_3O_8 conversion facility would be increased by 6 years, resulting in the generation of about 1,100 to 4,700 yd^3 (840 to 3,600 m^3) of additional LLW, 8 yd^3 (6 m^3) of additional LLMW, and 55 yd^3 (42 m^3) of additional hazardous waste. For conversion to UO_2, about 1,300 to 5,800 yd^3 (1,000 to 4,400 m^3) of additional LLW, 0 to 1,400 yd^3 (0 to 1,100 m^3) of additional LLMW, and 55 to 130 yd^3 (42 to 100 m^3) of additional hazardous waste would be generated. The construction impacts would be the same as those presented for DOE-generated cylinders. For conversion to U_3O_8, the total waste generated during operations (USEC and DOE-generated material) would be about 4,700 to 21,000 yd^3 (3,600 to 16,000 m^3) of LLW, 34 yd^3 (26 m^3) of LLMW, and 240 yd^3 (180 m^3) of hazardous waste. For conversion to UO_2, the total waste generated during operations (USEC and DOE-generated material) would be about 5,800 to 25,000 yd^3 (4,400 to 19,000 m^3) of LLW, 0 to 620 yd^3 (0 to 470 m^3) of LLMW, and 240 to 580 yd^3 (180 to 440 m^3) of hazardous waste. (The ranges are the result of assessing different conversion technologies.)

If CaF_2 was produced in the conversion process, and if the CaF_2 was disposed of as nonradioactive, nonhazardous solid waste, an additional 3,000 to 87,000 yd^3 (2,300 to 66,000 m^3) of nonradioactive, nonhazardous solid waste would be generated over the additional 6 years of operation. The capacity for managing this annual volume of nonhazardous waste would already be in place. If the CaF_2 was disposed of as LLW, the addition of about 170,000 yd^3 (128,000 m^3) of LLW would be generated over the additional 6 years of operation. (The additional volume would be the result of grouting.) In total, about 720,000 yd^3 (550,000 m^3) of CaF_2 LLW could be generated as a result of conversion to oxide. This quantity would represent about 13% of the projected DOE complexwide disposal volume for approximately the same time period, an amount that would represent a moderate impact on waste management if the LLW was considered to be DOE waste.

The duration of operational activities at a cylinder treatment facility would increase by 6 years, resulting in a total of about 380 yd^3 (290 m^3) of additional LLW, 1.6 yd^3 (1.2 m^3) of additional LLMW, and 16 yd^3 (12 m^3) of additional hazardous waste generated as a result of the inclusion of the USEC-generated cylinders. The construction impacts would be the same as those described for management of DOE-generated material. The total waste generated during treatment operations for both DOE- and USEC-generated cylinders would be about 1,600 yd^3 (1,200 m^3) of LLW, 6.8 yd^3 (5.2 m^3) of LLMW, and 68 yd^3 (52 m^3) of hazardous waste. The crushed cylinders, totaling about 37,000 m^3, would add an additional 1% to the projected DOE complexwide LLW disposal volume (if a decision for disposal was made). The total inventory of crushed cylinders would add an additional 4% to the projected DOE complexwide LLW disposal volume.

For the operation and construction of a consolidated long-term storage facility, the addition of the USEC cylinders would generate a maximum of about 8 yd^3 (6 m^3) of additional LLW from the repackaging of failed storage containers; the maximum total volume of LLW generated as a result of both the DOE- and USEC-generated inventory would be 34 yd^3 (26 m^3).

The generation of waste for all components under the long-term storage as oxide alternative (when both DOE- and USEC-generated cylinders are considered) would have a negligible to moderate impact when considered in terms of national and regional waste management capabilities.

6.3.3.8 Resource Requirements

In general, the addition of the USEC cylinders under the long-term storage as oxide alternative would not change the assessment of impacts on resource requirements presented in Section 5.3.8. The electrical requirement for mine construction would increase by up to 150 MW-yr to a total of 1,150 MW-yr. The impact of this high electrical requirement on use of local energy resources would depend on the location of the facility and the existing infrastructure.

6.3.3.9 Land Use

At the current storage sites, the impacts to land use from the addition of USEC-generated cylinders would be the same as that for management of DOE-generated cylinders described in Section 5.2.9. Storage space for the USEC cylinders is already present at the sites. If transfer facilities were built for cylinder preparation, the land use requirements would be the same as those for the DOE-generated cylinders only described in Section 5.2.9, because the facility operational period would increase, not the facility size. The land use required for a conversion facility would be the same as that for management of DOE-generated cylinders described in Section 5.3.9, because the size of the conversion facility would remain the same.

The increase in land use requirements at long-term storage facilities to accommodate the USEC-generated cylinders would range from 7 to 52 acres (3 to 21 ha). The total land use requirement for long-term storage as oxide for DOE- and USEC-generated cylinders combined would range from 81 to 264 acres (32 to 106 ha), constituting a moderate to large potential land use impact.

6.3.3.10 Cultural Resources

Potential impacts to cultural resources would be unlikely at the current storage sites because all activities would take place on previously developed land, and cultural impacts at a conversion or long-term storage facility would depend on the location of the facility.

6.3.3.11 Environmental Justice

No disproportionately high and adverse effects to minority or low-income populations would be expected in the vicinity of the Paducah and Portsmouth sites in association with the addition of the USEC-generated cylinders under the long-term storage as oxide alternative.

6.3.4 Use as Uranium Oxide

Under the use as uranium oxide alternative, the inclusion of USEC-generated cylinders would increase the number of cylinders managed by DOE at the Paducah site by 42% and at the Portsmouth site by 22%. Activities occurring at the K-25 site would be unaffected. Consequently, the duration of continued cylinder storage at the Paducah and Portsmouth sites would be extended by about 6 years, from 2028 to 2034. In addition, the total number of shipments of cylinders, uranium oxide, HF, uranium-oxide-shielded casks, and associated materials would increase by about 30%, although the annual number of shipments would be unchanged. The operational period for conversion and manufacturing facilities would be extended from 20 to 26 years to accommodate the additional processing of USEC-generated cylinders, but the sizes of these facilities would remain unchanged.

6.3.4.1 Human Health and Safety

6.3.4.1.1 Normal Facility Operations

For the use as uranium oxide alternative, the management of USEC-generated cylinders would increase the level of exposure of workers and members of the public to radiation and chemicals when compared with the management of DOE-generated cylinders only as presented in Chapter 5. However, the increased levels of exposure would not be large enough to cause appreciable increases in the potential health impacts over those under the use as uranium oxide alternative discussed in Chapter 5.

Workers. Under the use as uranium oxide alternative, the management of the additional USEC-generated cylinders (including continued cylinder storage, cylinder preparation, conversion, empty cylinder treatment, and manufacture and use) was estimated to increase the total dose to involved workers by about 30%. However, this increase would not result in additional health effects among workers when compared with the management of DOE-generated cylinders only. (The number of LCFs would not change because of rounding effects and the fact that estimates are presented as whole numbers.) The total number of health effects among involved workers (when both DOE- and USEC-generated cylinders are considered) would still range from 1 to 2 LCFs over the duration of the program. (The dose to noninvolved workers would remain negligible when compared with the involved worker dose.)

In general, the average annual radiation dose to individual workers associated with management of the additional USEC cylinders would be the same as that for DOE-generated cylinders reported on in Chapter 5 (i.e., well within applicable standards) because (1) at the current storage sites, additional cylinder yard workers would be used instead of having the same individuals conduct extra activities, and (2) at conversion and manufacturing facilities, the annual worker activities would be the same, but the facilities would operate over a longer period of time.

Increased exposure to chemicals would not be expected to increase health impacts on involved or noninvolved workers; the total estimated hazard indices (when both DOE- and USEC-generated cylinders are considered) would be less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, or a manufacturing facility.

General Public. The overall potential impacts to members of the general public during normal operations would be the same as those for the management of DOE-generated cylinders described in Section 5.4.1.1.2: all exposures would be within applicable public health standards, and no LCFs from radiation exposures and no adverse effects from chemical exposures would be expected to occur among members of the general public near the three current storage sites, a conversion facility, or a manufacturing facility, when the management of additional USEC cylinders is considered.

At the current storage sites, potential public exposure to radiation and chemicals released from the sites would be exactly the same as that under the long-term storage as UF_6 alternative described in Section 6.3.2.1.1.

At conversion and manufacturing facilities, the annual impacts to members of the public would be the same as those for management of DOE-generated cylinders described in Section 5.4.1.1.2, because the annual operations would be the same. The total exposure of the public in the vicinity of these facilities to airborne radiation and chemicals would increase by approximately 30% as a result of the processing of USEC-generated cylinders. However, total exposure levels would remain well within standards and below levels expected to cause any adverse health effects among the public for all options.

6.3.4.1.2 Facility Accidents

Physical Hazards (On-the Job Injuries and Fatalities). For the use as uranium oxide alternative, it was estimated that no (zero) additional worker fatalities and up to 600 additional worker injuries could occur in association with management of the USEC-generated cylinders (including continued storage, cylinder preparation, cylinder treatment, conversion to oxide, and manufacture of uranium-oxide-shielded casks). The total physical hazards associated with management of the DOE- and USEC-generated cylinders would range from 2 to 3 worker fatalities and 1,600 to 2,600 worker injuries.

Accidents Involving Releases of Radiation or Chemicals. For accident consequences, impacts would be the same as those for the DOE-generated cylinders under the use as uranium oxide alternative discussed in Section 5.4.1.2.2. Although the estimated frequencies of some accidents would increase somewhat in association with the management of the additional USEC cylinders, this increase would not be expected to be enough to change the overall expected frequency of specific accidents from the broad ranges used for this PEIS.

6.3.4.2 Transportation

The management of the USEC-generated cylinders would result in an increase of approximately 30% in the total number of shipments of UF_6 cylinders, uranium oxide, ammonia, anhydrous HF (if produced), CaF_2 (if produced), uranium-oxide-shielded casks, and waste materials. (The annual number of shipments would be the same as that for DOE-generated cylinders described in Section 5.4.2 and Appendix J.) For normal (incident-free) transportation operations, these additional shipments would increase exposure to overall external radiation and vehicle exhaust emissions by about 30%. However, no adverse health effects would be expected among workers and the public during normal transportation activities when shipment of both DOE- and USEC-generated cylinders and associated materials is considered.

The 30% increase in the total number of shipments would not change the estimated number of fatalities from truck accidents (not involving releases of radioactive or hazardous materials) presented in Section 5.4.2: 4 fatalities from truck shipments (because of rounding). However, the estimated number of fatalities from rail shipment accidents would increase by 1, from 2 to 3, over the duration of the program.

The consequences of severe traffic accidents involving releases of radiation or chemicals would be the same as those for the shipment of DOE-generated cylinders and associated materials described in Section 5.4.2, because the shipment sizes would not change. The annual probability of severe accidents occurring also would be the same as that discussed in Section 5.4.2, although the total probability of a severe accident would increase by about 30% as shipments continued for an additional 6 years.

6.3.4.3 Air Quality

At the current storage sites, potential impacts to air quality would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.3. At an oxide conversion facility, the potential air quality impacts would be identical to those under the long-term storage as oxide alternative discussed in Section 6.3.3.3.

At a cask manufacturing facility, impacts on criteria pollutant emissions from construction and operation would be identical to those for DOE-generated cylinders only discussed in

Section 5.4.3, because manufacturing facilities would not increase in size, only in duration of operations. During an additional 6 years of operation, an additional 0.1 lb (0.048 kg) of uranium (as UO_2) would be emitted. The total uranium emissions from oxide cask manufacture of both the DOE- and USEC-generated inventory would be about 0.46 lb (0.21 kg). No air quality standards exist for uranium compounds. However, the additional radiological dose from these emissions was evaluated in Section 6.3.4.1.1.

6.3.4.4 Water and Soil

At the current storage sites, potential impacts to surface water, groundwater, and soil would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.4. At a conversion facility, impacts to water use and surface water, groundwater, and soil quality would be identical to those under the long-term storage as oxide alternative discussed in Section 6.3.3.4.

During construction of an oxide cask manufacturing facility, water use requirements would be the same as those for DOE-generated cylinders described in Section 5.4.4. The duration of operational activities at a cask manufacturing facility would increase by 6 years, so about 45 million gal of additional water would be required for operations. About 30 million gal of additional wastewater would be generated over the additional 6 years of operation. The total water requirement for oxide cask manufacturing facility operations would be about 200 million gal; the total operational wastewater generated would be about 130 million gal.

At a cask manufacturing facility, potential impacts to surface water, groundwater, and soil would depend on the actual location of the facility. Impacts from the DOE cylinders only were expected to be negligible, as discussed in Section 5.4.4. Impacts from the additional USEC-generated cylinders would also likely be negligible.

6.3.4.5 Socioeconomics

At the current storage sites, socioeconomic impacts would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.5.

The annual socioeconomic impacts from operating a conversion to oxide facility and an oxide cask manufacturing facility would be the same as those for the DOE-generated cylinders only presented in Section 5.4.5. However, the period of operation would be extended by 6 years. Socioeconomic impacts during construction would also be the same as those described in Section 5.4.5.

6.3.4.6 Ecology

The continued cylinder storage and preparation activities associated with management of the USEC-generated cylinders at the current storage sites would not result in additional impacts to ecological resources. Concentrations of uranium in soil, groundwater, and surface water would remain well below benchmark values for toxic and radiological effects. In addition, construction activities would take place on previously disturbed areas (i.e., existing yards) and would have no ecological impacts.

At conversion and manufacturing facilities, treatment of USEC-generated cylinders would not result in any additional land use requirements or habitat loss, because the size of the facilities would not change when compared with those described in Section 5.4.6.

6.3.4.7 Waste Management

At the current storage sites, potential impacts to waste management would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.7.

Waste management impacts from conversion activities (including disposal of CaF_2, if necessary, and empty cylinder treatment) would be identical to those under the long-term storage as oxide alternative discussed in Section 6.3.3.7.

Waste generation during construction of a manufacturing facility would be the same as that for DOE-generated cylinders described in Section 5.4.7, because the design and size of the manufacturing facility would not change. During operation of a manufacturing facility, the addition of the USEC-generated cylinders would not change the amount of LLW generated annually; this amount would still be about 0.2% of the projected annual LLW treatment volume for all DOE facilities as described in Section 5.4.7. Operation of the manufacturing facility would generate about 1,000 yd^3 (780 m^3) of additional LLW, 2,200 yd^3 (1,700 m^3) of additional hazardous waste, and 1,500 metric tons of nonradioactive, nonhazardous solid waste. The total volume of LLW generated for processing of both the DOE- and USEC-generated cylinders would be about 4,400 yd^3 (3,400 m^3); the total volume of hazardous waste would be about 9,800 yd^3 (7,500 m^3); and the total volume of nonradioactive, nonhazardous solid waste would be about 6,500 metric tons.

The generation of waste for all components under the use as oxide alternative (when both DOE- and USEC-generated cylinders are considered) would have a low to moderate impact when considered in terms of national and regional waste management capabilities.

6.3.4.8 Resource Requirements

Addition of the USEC-generated cylinders under the use as uranium oxide alternative would not change the assessment of impacts on resource requirements presented in Section 5.4.8: no significant impacts would be expected because construction and operational requirements would not be resource intensive, and the resources required would not be rare or unique.

6.3.4.9 Land Use

At the current storage sites, the impacts to land use from the addition of USEC-generated cylinders would be the same as that for management of DOE-generated cylinders described in Section 5.2.9. Storage space for the USEC cylinders is already present at the sites. If transfer facilities were built for cylinder preparation, the land use requirements would be the same as those for the DOE-generated cylinders only described in Section 5.2.9, because the facility operational period would increase, not the facility size. The land use required for conversion and manufacturing facilities would be the same as that for management of DOE-generated cylinders described in Section 5.4.9, because the facility sizes would remain the same.

6.3.4.10 Cultural Resources

The potential impacts to cultural resources would be the same as those for the DOE-generated cylinders under the use as uranium oxide alternative discussed in Section 5.4.10. Impacts to cultural resources would be unlikely at the current storage sites because all activities would take place on previously developed land, and cultural impacts at a conversion or manufacturing facility would depend on the location of the facility.

6.3.4.11 Environmental Justice

The potential impacts to environmental justice would be the same as those for the DOE-generated cylinders under the long-term storage as oxide alternative discussed in Section 5.4.11.

6.3.5 Use as Uranium Metal

Under the use as uranium metal alternative, the inclusion of USEC-generated cylinders would increase the number of cylinders managed by DOE at the Paducah site by 42% and at the Portsmouth site by 22%. Activities occurring at the K-25 site would be unaffected. Consequently, the duration of continued cylinder storage at the Paducah and Portsmouth sites would be extended by about 6 years, from 2028 to 2034. In addition, the total number of shipments of cylinders, uranium oxide, HF, uranium-metal-shielded casks, and associated materials would increase by about 30%, although the annual number of shipments would be unchanged. The operational period for conversion and manufacturing facilities would be extended from 20 to 26 years to accommodate the additional processing of USEC-generated cylinders, but the sizes of these facilities would remain unchanged.

6.3.5.1 Human Health and Safety

6.3.5.1.1 Normal Facility Operations

For the use as metal alternative, the management of USEC-generated cylinders would increase the level of exposure of workers and members of the public to radiation and chemicals when compared with the management of DOE-generated cylinders only as presented in Chapter 5. However, the increased levels of exposure would not be large enough to cause appreciable increases in the potential health impacts over those under the use as metal alternative discussed in Chapter 5.

Workers. Under the use as metal alternative, the management of the additional USEC-generated cylinders (including continued cylinder storage, cylinder preparation, conversion, empty cylinder treatment, and manufacture and use) was estimated to increase the total dose to involved workers by about 30%. However, this increase would not result in additional health effects among workers when compared with the management of DOE-generated cylinders only. The total number of health effects among involved workers (when both DOE- and USEC-generated cylinders are considered) would still range from 1 to 2 LCFs over the duration of the program. (The dose to noninvolved workers would remain negligible when compared with the involved worker dose.)

In general, the average annual radiation dose to individual workers associated with management of the additional USEC cylinders would be the same as that for DOE-generated cylinders reported on in Chapter 5 (i.e., well within applicable standards) because (1) at the current storage sites, additional cylinder yard workers would be used instead of having the same individuals conduct extra activities, and (2) at conversion and manufacturing facilities, the annual worker activities would be the same, but the facilities would operate over a longer period of time.

Increased exposure to chemicals would not be expected to increase health impacts on involved or noninvolved workers. The total estimated hazard indices (when both DOE- and USEC-generated cylinders are considered) would be less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, or a manufacturing facility.

General Public. The overall potential impacts to members of the general public during normal operations would be the same as those for the management of DOE-generated cylinders described in Section 5.5.1.1.2: all exposures would be within applicable public health standards, and no LCFs from radiation exposures and no adverse effects from chemical exposures would be expected to occur among members of the general public near the three current storage sites, a conversion facility, or a manufacturing facility, when the management of additional USEC cylinders is considered.

At the current storage sites, potential public exposure to radiation and chemicals released from the sites would be exactly the same as that for the long-term storage as UF_6 alternative described in Section 6.3.2.1.1.

At conversion and manufacturing facilities, the annual impacts to members of the public would be the same as those for management of DOE-generated cylinders described in Section 5.5.1.1.2, because the annual operations would be the same. The total exposure of the public in the vicinity of these facilities to airborne radiation and chemicals would increase by approximately 30% as a result of the processing of USEC-generated cylinders. However, total exposure levels would remain well within standards and below levels expected to cause any adverse health effects among the public for all options.

6.3.5.1.2 Facility Accidents

Physical Hazards (On-the Job Injuries and Fatalities). For the use as metal alternative, it was estimated that no (zero) additional worker fatalities and up to 600 additional worker injuries could occur in association with the management of the USEC-generated cylinders (including continued storage, cylinder preparation, empty cylinder treatment, conversion to metal, and manufacture of metal casks). The total physical hazards associated with management of the DOE- and USEC-generated cylinders would range from 2 to 3 worker fatalities and 1,700 to 2,700 worker injuries.

Accidents Involving Releases of Radiation or Chemicals. For accident consequences, impacts would be the same as those for the DOE-generated cylinders under the use as metal alternative discussed in Section 5.5.1.2.2. Although the estimated frequencies of some accidents would increase somewhat in association with the management of the additional USEC cylinders, this increase would not be expected to be enough to change the overall expected frequency of specific accidents from the broad ranges used for this PEIS.

6.3.5.2 Transportation

The management of the USEC-generated cylinders would result in an increase of approximately 30% in the total number of shipments of UF_6 cylinders, uranium metal, ammonia, anhydrous HF (if produced), CaF_2 (if produced), MgF_2, uranium-metal-shielded casks, and waste materials. (The annual number of shipments would be the same as that for DOE-generated cylinders described in Section 5.5.2 and Appendix J). For normal (incident-free) transportation operations, these additional shipments would increase exposure to overall external radiation and vehicle exhaust emissions by about 30%. However, no adverse health effects would be expected among workers and the public during normal transportation activities when shipment of both DOE- and USEC-generated cylinders and associated materials is considered.

The 30% increase in the total number of shipments would increase the estimated number of fatalities from truck and rail accidents (not involving releases of radioactive or hazardous materials) presented in Section 5.5.2. The estimated number of fatalities from truck shipments would increase from 3 to 4. The estimated number of fatalities from rail shipments would increase from 1 to 2 over the duration of the program.

The consequences of severe traffic accidents involving releases of radiation or chemicals would be the same as those for the shipment of DOE-generated cylinders and associated materials described in Section 5.5.2, because the shipment sizes would not change. The annual probability of severe accidents occurring also would be the same as that discussed in Section 5.5.2, although the total probability of a severe accident would increase by about 30% as shipments continued for an additional 6 years.

6.3.5.3 Air Quality

At the current storage sites, potential impacts to air quality would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.3.

At a metal conversion facility, impacts on criteria pollutant emissions from construction and operation would be identical to those for DOE-generated cylinders only under the use as metal alternative discussed in Section 5.5.3, because conversion facilities would not increase in size, only in duration of operations. During an additional 6 years of operation, an additional 24 to 66 lb (11 to 30 kg) of uranium (as U_3O_8 or UF_4) would be emitted. The total uranium emissions from conversion of both the DOE- and USEC-generated inventory would range from about 100 to 290 lb (45 to 130 kg). No air quality standards exist for uranium compounds. However, the potential health impacts from these emissions were evaluated in Section 6.3.5.1.1.

At a cask manufacturing facility, impacts on criteria pollutant emissions from construction and operation would be identical to those for DOE-generated cylinders only discussed in Section 5.5.3, because manufacturing facilities would not increase in size, only in duration of operations. During an additional 6 years of operation, an additional 0.66 lb (0.30 kg) of uranium (as U_3O_8) would be emitted. The total uranium emissions from metal cask manufacture of both the DOE- and USEC-generated inventory would be about 2.9 lb (1.3 kg). No air quality standards exist for uranium compounds. However, the additional radiological dose from these emissions was evaluated in Section 6.3.5.1.1.

6.3.5.4 Water and Soil

At the current storage sites, potential impacts to surface water, groundwater, and soil would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.4.

During construction of a metal conversion facility, water use requirements would be the same as those for DOE-generated cylinders described in Section 5.5.4. The duration of operational activities at a conversion to metal facility would increase by 6 years, so about 330 million gal of additional water would be required for operations. From about 150 to 180 million gal of additional wastewater would be generated over the additional 6 years of operation. The total water requirement for conversion to metal operations would be about 1,400 million gal; the total wastewater generated would range from about 650 to 780 million gal.

During construction of a cask manufacturing facility, water use requirements would be the same as those for DOE-generated cylinders described in Section 5.5.4. The duration of operational activities at a metal cask manufacturing facility would increase by 6 years, so about 42 million gal of additional water would be required for operations. About 30 million gal of additional wastewater would be generated over the additional 6 years of operation. The total water requirement for metal cask manufacturing facility operations would be about 180 million gal; the total operational wastewater generated would be about 130 million gal.

At a metal cask manufacturing facility, potential impacts to surface water, groundwater, and soil would depend on the actual location of the facility. Impacts for the DOE-cylinders only were expected to be negligible, as described in Section 5.5.4. Impacts from the additional USEC-generated cylinders would also likely be negligible.

6.3.5.5 Socioeconomics

At the current storage sites, socioeconomic impacts would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.5.

The annual socioeconomic impacts from operating a conversion to metal facility and metal cask manufacturing facility would be the same as those for the DOE-generated cylinders only presented in Section 5.5.5. However, the period of operations would be extended by 6 years. Socioeconomic impacts during construction would also be the same as those described in Section 5.5.5.

6.3.5.6 Ecology

The continued cylinder storage and preparation activities associated with management of the USEC-generated cylinders at the current storage sites would not result in additional impacts to ecological resources. Concentrations of uranium in soil, groundwater, and surface water would remain well below benchmark values for toxic and radiological effects. In addition, construction activities would take place on previously disturbed areas (i.e., existing yards) and would have no ecological impacts.

At conversion and manufacturing facilities, treatment of USEC-generated cylinders would not result in any additional land use requirements or habitat loss, because the sizes of the facilities would not change when compared with those described in Section 5.5.6.

6.3.5.7 Waste Management

At the current storage sites, potential impacts to waste management would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.7.

At a metal conversion facility, the impacts during construction would be the same as those for DOE-generated cylinders described in Section 5.5.7. Operation of the metal conversion facility would increase by 6 years, so about 1,400 to 14,000 yd^3 (1,100 to 11,000 m^3) of additional LLW, 8 yd^3 (6 m^3) of additional LLMW, and 55 to 78 yd^3 (42 to 60 m^3) of additional hazardous waste would be generated as a result of including the USEC-generated cylinders. The total waste generated during operations for conversion of both DOE- and USEC-generated cylinders would be about 6,400 to 64,000 yd^3 (4,900 to 49,000 m^3) of LLW, 34 yd^3 (26 m^3) of LLMW, and 230 to 340 yd^3 (180 to 260 m^3) of hazardous waste. (The ranges are the result of assessing different conversion technologies.)

If MgF_2 produced in the conversion process was disposed of as nonradioactive, nonhazardous solid waste, an additional 48,000 yd^3 (37,000 m^3) of nonradioactive, nonhazardous solid waste would be generated. This additional waste would be disposed of annually (about 7,900 yd^3 [6,100 m^3] per year) over the additional 6 years of operation of the conversion facility. The capacity for managing this annual volume of nonhazardous waste would already be in place. If the MgF_2 needed to be disposed of as LLW, an additional 96,000 yd^3 (74,000 m^3) of LLW would be generated over the additional 6 years of operation. This additional volume would be a result of grouting. In total, about 420,000 yd^3 (320,000 m^3) of MgF_2 LLW could be generated through conversion to metal. This amount of LLW would represent less than 8% of the projected DOE complexwide disposal volume for approximately the same time period, which would be considered a low impact for waste management if the LLW was considered DOE waste. If HF was neutralized to produce CaF_2, and if the CaF_2 needed to be disposed of as LLW, an additional 27,000 yd^3 (21,000 m^3) of CaF_2 would be produced, yielding a total of 120,000 yd^3 (91,000 m^3) of grouted CaF_2 LLW. This additional volume of LLW would constitute approximately 4% of the projected DOE complexwide LLW disposal volume.

Waste generation during construction of a metal cask manufacturing facility would be the same as that for DOE-generated cylinders described in Section 5.5.7, because the design and size of the manufacturing facility would not change. During operation of a manufacturing facility, the addition of the USEC-generated cylinders would not change the amount of LLW generated annually; this amount would still be about 0.3% of the projected annual LLW treatment volume for all DOE facilities, as described in Section 5.4.7. Operation of the manufacturing facility would generate about 5,100 yd^3 (3,900 m^3) of additional LLW, 2,500 yd^3 (1,900 m^3) of additional hazardous waste, and 1,800 metric tons of nonradioactive, nonhazardous solid waste. The total volume of LLW generated for processing of both the DOE- and USEC-generated cylinders would be about 22,000 yd^3 (17,000 m^3); the total volume of hazardous waste would be about 1,100 yd^3 (8,300 m^3); and the total volume of nonradioactive, nonhazardous solid waste would be about 7,800 metric tons.

The generation of waste for all components of the use as metal alternative (when both DOE- and USEC-generated cylinders are considered) would have a low to moderate impact when considered in terms of national and regional waste management capabilities.

6.3.5.8 Resource Requirements

The addition of the USEC-generated cylinders under the use as uranium metal alternative would not change the assessment of impacts on resource requirements presented in Section 5.5.8: no significant impacts would be expected, because construction and operational requirements would not be resource intensive, and the resources required would not be rare or unique.

6.3.5.9 Land Use

At the current storage sites, the impacts to land use from the addition of USEC-generated cylinders would be the same as that for management of DOE-generated cylinders described in Section 5.2.9. Storage space for the USEC cylinders is already present at the sites. If transfer facilities were built for cylinder preparation, the land use requirements would be the same as those given for the DOE-generated cylinders only described in Section 5.2.9, because the facility operational period would increase, not the facility size. The land use required for conversion and manufacturing facilities would be the same as that for management of DOE-generated cylinders described in Section 5.5.9, because the facility sizes would remain the same.

6.3.5.10 Cultural Resources

For the use as uranium metal alternative, impacts to cultural resources would be unlikely at the current storage sites, because all activities would take place on previously developed land, and cultural impacts at a conversion or manufacturing facility would depend on the location of the facility.

6.3.5.11 Environmental Justice

The impacts to environmental justice would be the same as those for the DOE-generated cylinders under the use as metal alternative discussed in Section 5.5.11.

6.3.6 Disposal as Uranium Oxide

Under the disposal as uranium oxide alternative, the inclusion of USEC-generated cylinders would increase the number of cylinders managed by DOE at the Paducah site by 42% and at the Portsmouth site by 22%. Activities occurring at the K-25 site would be unaffected. Consequently, the duration of continued cylinder storage at the Paducah and Portsmouth sites would be extended by about 6 years, from 2028 to 2034. In addition, the total number of shipments of cylinders, uranium oxide, HF, and associated materials would increase by about 30%, although the annual number of shipments would be unchanged. The operational period for a conversion facility would be extended from 20 to 26 years to accommodate the additional processing of USEC-generated cylinders. Similarly, the operational period of a disposal facility would also be increased from 20 to 26 years, with approximately 30% more land area being required for disposal.

6.3.6.1 Human Health and Safety

6.3.6.1.1 Normal Facility Operations

For the disposal as uranium oxide alternative, the management of USEC-generated cylinders would increase the level of exposure of workers and members of the public to radiation and chemicals when compared with the management of DOE-generated cylinders only, as presented in Chapter 5. For involved workers, the increased radiation exposure could result in a maximum of 1 LCF in addition to the potential 1 to 2 LCFs estimated for the management of DOE-generated cylinders. (The estimated total including DOE- and USEC-generated cylinders would be 1 to 3 LCFs.) For noninvolved workers and members of the public, the increased levels of exposure would not appreciably increase the potential health impacts over those under the disposal as oxide alternative discussed in Chapter 5. For a disposal facility in a wet environment, potential long-term exposure of members of the public to radiation and chemicals from groundwater could exceed standards and levels expected to cause adverse health effects. For a disposal facility in a dry environment, no long-term impacts would be expected.

Workers. Under the disposal as oxide alternative, the management of the additional USEC cylinders (including continued cylinder storage, cylinder preparation, conversion, empty cylinder treatment, and disposal of oxide) was estimated to increase the total dose to involved workers by about 30%, resulting in a maximum of 1 additional LCF for each disposal option (shallow-earthen structures, vaults, and mines). The total number of health effects among involved workers (when both DOE- and USEC-generated cylinders are considered) would range from 1 to 3 LCFs over the duration of the program. (The dose to noninvolved workers would remain negligible when compared with the involved worker dose.)

In general, the average annual radiation dose to individual workers associated with management of the additional USEC cylinders would be the same as that for DOE-generated cylinders reported on in Chapter 5 (i.e., well within applicable standards) because (1) at the current storage sites, additional cylinder yard workers would be used instead of having the same individuals conduct extra activities, and (2) at conversion and disposal facilities, the annual worker activities would be the same, but the facilities would operate over a longer period of time.

Increased exposure to chemicals would not be expected to increase health impacts on involved or noninvolved workers; the total estimated hazard indices (when both DOE- and USEC-generated cylinders are considered) would be less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, or a disposal facility.

General Public. During the operational phase of the disposal facility, the overall potential impacts to members of the general public during normal operations would be the same as those for the management of DOE-generated cylinders described in Section 5.6.1.1.2: all exposures would be within applicable public health standards, and no LCFs from radiation exposures and no adverse effects from chemical exposures would be expected to occur among members of the general public near the three current storage sites, a conversion facility, or a disposal facility, when the management of additional USEC cylinders is considered.

At the current storage sites, potential public exposure to radiation and chemicals released from the sites would be exactly the same as that for the long-term storage as UF_6 alternative described in Section 6.3.2.1.1.

At a conversion facility or a disposal facility during the operational phase, the annual impacts to members of the public would be the same as those for management of DOE-generated cylinders described in Section 5.6.1.1.2, because the annual operations would be the same. The total exposure of the public to airborne radiation and chemicals in the vicinity of these facilities would increase by approximately 30% as a result of the processing of USEC-generated cylinders. However, total exposure levels during the operational phase would remain well within standards and below levels expected to cause any adverse health effects among the public for all disposal options.

For a disposal facility located in a wet environment, during the postclosure phase (long-term), potential exposures of members of the public to radiation and chemicals in groundwater could increase as a result of the additional management of USEC-generated cylinders. (For a disposal facility in a dry environment, groundwater contamination would not occur until well after the 1,000-year assessment period considered in the PEIS.) As described in the groundwater analysis in Section 6.3.6.4, in a wet environment, the addition of the USEC-generated cylinders would increase the uranium concentration in groundwater by 20% 1,000 years after facility failure (Tomasko 1998).

The potential radiation dose and chemical intakes for a maximally exposed individual would increase proportionally. The maximum radiation dose to an individual assumed to use contaminated groundwater would be expected to increase to about 120 mrem/yr, a level that is greater than the dose limit of 25 mrem/yr specified in 10 CFR Part 61. The chemical hazard indices were calculated to increase to 12, indicating the potential for chemically induced adverse effects.

6.3.6.1.2 Facility Accidents

Physical Hazards (On-the Job Injuries and Fatalities). Under the disposal as uranium oxide alternative, it was estimated that no (zero) additional worker fatalities and up to 600 additional worker injuries could occur in association with the management of the USEC-generated cylinders (including continued cylinder storage, cylinder preparation, cylinder treatment, conversion, and disposal). The total physical hazards associated with management of the DOE- and USEC-generated cylinders would range from 1 to 3 worker fatalities and 900 to 2,400 worker injuries.

Accidents Involving Releases of Radiation or Chemicals. For accident consequences, impacts would be the same as those for the DOE-generated cylinders under the disposal as uranium oxide alternative discussed in Section 5.6.1.2.2. Although the estimated frequencies of some accidents would increase somewhat in association with the management of the additional USEC cylinders, this increase would not be expected to be enough to change the overall expected frequency of specific accidents from the broad ranges used for this PEIS.

6.3.6.2 Transportation

The management of the USEC-generated cylinders would result in an increase of approximately 30% in the total number of shipments of UF_6 cylinders, uranium oxide, ammonia, anhydrous HF (if produced), CaF_2 (if produced), and waste materials. (The annual number of shipments would be the same as that for DOE-generated cylinders described in Section 5.6.2 and Appendix J.) For normal (incident-free) transportation operations, these additional shipments would increase exposure to overall external radiation and vehicle exhaust emissions by about 30%. However, no adverse health effects would be expected among workers and the public during normal transportation activities when shipment of both DOE- and USEC-generated cylinders and associated materials is considered.

Although the total number of shipments would increase by about 30%, the estimated number of fatalities from transportation accidents (not involving releases of radioactive or hazardous materials) would be the same as that for DOE-generated cylinders reported on in Section 5.6.2. The number would be the same because of rounding and the fact that estimates were presented as a single whole number. Thus, the total estimated number of traffic accident fatalities under the disposal as oxide alternative (including both DOE- and USEC-generated cylinders) would remain at 4 for truck transport and 2 for rail transport.

The consequences of severe traffic accidents involving releases of radiation or chemicals would be the same as those for the shipment of DOE-generated cylinders and associated materials described in Section 5.6.2, because the shipment sizes would not change. The annual probability of severe accidents occurring also would be the same as that discussed in Section 5.6.2, although the total probability of a severe accident would increase by about 30% as shipments continued for an additional 6 years.

6.3.6.3 Air Quality

At the current storage sites, potential impacts to air quality would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.3. At a conversion facility, potential impacts to air quality would be identical to those for conversion under the long-term storage as oxide alternative discussed in Section 6.3.3.3.

At a disposal facility, although the size of the facility would increase, annual average air concentrations of criteria pollutants would remain the same as those predicted for the DOE-generated cylinders only in Section 5.6.3, because the annual level of operations would stay the same. For disposal options that involve the grouting of waste, during an additional 6 years of operation, an additional 3.6 to 6.6 lb (1.6 to 3 kg) of uranium (as U_3O_8 or UO_2) would be emitted. The total uranium emissions from disposal of grouted U_3O_8 or UO_2 for both the DOE- and USEC-generated inventory would range from about 16 to 29 lb (7 to 13 kg). No air quality standards exist for uranium compounds. However, the potential health impacts from these emissions were evaluated in Section 6.3.6.1.1.

6.3.6.4 Water and Soil

At the current storage sites, potential impacts to water and soil would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.4. At an oxide conversion facility, potential impacts to water and soil would be identical to those for conversion under the long-term storage as oxide alternative discussed in Section 6.3.3.4.

At a disposal facility, the addition of the USEC-generated cylinders would require that construction and operational activities be increased by 6 years. Therefore, about 1.2 to 17 million gal of additional water would be required for construction, and about 0.6 to 120 million gal of additional water would be required for operations. Additional wastewater generation would range from about 0.6 to 1.2 million gal for construction and 0.6 to 8 million gal for operations. The total water requirement for construction would range from 5 to 73 million gal; the total water requirement for operations would range from about 3 to 520 million gal. Total wastewater generation would range from about 3 to 5 million gal for construction and 3 to 34 million gal for operations.

As stated in Section 5.6.4.1, impacts to surface water from a disposal facility would be negligible, because no process water effluents would be expected and because wastewater generation rates would be half or less than half of those from a conversion facility. Additional impacts of disposal to surface water as a result of the additional USEC-generated cylinders would also be negligible.

Potential impacts to groundwater during the operational phase of disposal when the USEC cylinders are considered would be the same as the impacts for the DOE-generated cylinders only described in Section 5.6.4.2.1.

Potential long-term impacts to groundwater from disposal of DOE-generated cylinders only were discussed in Section 5.6.4.2.2. The addition of the USEC cylinders to the disposal inventory would increase the total subsurface disposal area, which ultimately would increase the estimated concentration of uranium in groundwater by 20% 1,000 years after failure of the facility (Tomasko 1998). This increase would not impact the assessment for disposal in a dry environment (i.e., concentrations greater than the guideline level of 20 µg/L would not occur for at least 1,000 years after failure of the facility). For disposal in a wet environment, the inclusion of the USEC cylinders in the disposal calculations would result in estimated concentrations of uranium in groundwater at 1,000 years after facility failure that would range from about 280 to 510 pCi/L (1,100 to 2,000 µg/L) for disposal of U_3O_8 and about 230 to 380 pCi/L (910 to 1,600 µg/L) for disposal of UO_2.

The additional excavation volume that would result from the addition of the USEC cylinders under the disposal as uranium oxide alternative would range from 70,000 yd^3 (54,000 m^3) for disposal as ungrouted UO_2 in a vault to 1 million yd^3 (770,000 m^3) for disposal as grouted U_3O_8 in a mine. The total required excavation volumes would range from 400,000 yd^3 (310,000 m^3) to 3.6 million yd^3 (230,000 to 2.8 million m^3).

6.3.6.5 Socioeconomics

At the current storage sites, socioeconomic impacts would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.5.

The annual socioeconomic impacts from operating a conversion to oxide facility and a disposal facility would be the same as those for the DOE-generated cylinders only presented in Section 5.6.5. However, the period of operation would be extended by 6 years. Socioeconomic impacts during construction would not change for the conversion facility. However, the period of construction activities for the disposal facility would increase by 6 years.

6.3.6.6 Ecology

The continued cylinder storage and preparation activities associated with management of the USEC-generated cylinders at the current storage sites would not result in additional impacts to ecological resources. Concentrations of uranium in soil, groundwater, and surface water would remain well below benchmark values for toxic and radiological effects. In addition, construction activities would take place on previously disturbed areas (i.e., existing yards) and would have no ecological impacts.

At a conversion facility, treatment of USEC-generated cylinders would not result in any additional land use requirements or habitat loss, because the size of the facilities would not change when compared with those described in Section 5.6.6.

For the operational phase of the disposal facility, addition of the USEC-generated cylinders would increase land use requirements by 8 to 116 acres (3 to 46 ha), which would result in additional habitat loss. The total land required for a disposal facility would range from 36 to 587 acres (14 to 230 ha), which would have a moderate to large potential impact on vegetation and wildlife.

Although the postclosure groundwater uranium concentrations at disposal facilities might increase somewhat (i.e., by about 20%) as a result of the addition of the USEC-generated cylinders, the overall ecological impacts during the postclosure phase would remain the same as those discussed in Section 5.6.6.2.

6.3.6.7 Waste Management

At the current storage sites, potential impacts on waste management would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.7. At an oxide conversion facility, impacts would be identical to those under the long-term storage as oxide alternative discussed in Section 6.3.3.7.

At a disposal facility, the inclusion of the USEC-generated cylinders would increase disposal volumes by approximately 30%. Thus, the maximum volume of grouted U_3O_8 for disposal would increase by approximately 130,000 yd^3 (100,000 m^3), to a total of 540,000 yd^3 (412,000 m^3). This amount would represent approximately 10% of the projected DOE complexwide LLW disposal volume over the same approximate period. If the U_3O_8 was not grouted, an additional 65,000 yd^3 (50,000 m^3) would be disposed of, for a total of about 260,000 yd^3 (200,000 m^3), representing about 5% of the projected DOE disposal volume. The volumes of UO_2 disposed of would increase by approximately 30,000 yd^3 (23,000 m^3) if grouted and 20,000 yd^3 (15,000 m^3) if ungrouted, for totals of about 120,000 yd^3 (95,000 m^3) grouted and 82,000 yd^3 (63,000 m^3) ungrouted. These volumes represent less than about 2.2% of the projected DOE disposal volume. Overall, the additional volumes represent a range of potential waste management impacts from low to moderate.

The generation of waste for all components under the disposal alternative (when both DOE- and USEC-generated cylinders are considered) would have a low to moderate impact when considered in terms of national and regional waste management capabilities.

6.3.6.8 Resource Requirements

In general, addition of the USEC cylinders would not change the assessment of impacts on resource requirements from those under the disposal alternative presented in Section 5.6.8; no significant impacts would be expected because construction and operational requirements would not be resource intensive, and the resources required would not be considered rare or unique. The maximum electrical requirement for mine construction would increase by approximately 200 MW-yr, to a total of 1,300 MW-yr. The impact of this high electrical requirement on use of local energy resources would depend on the location of the facility and the existing infrastructure.

6.3.6.9 Land Use

At the current storage sites, the impacts to land use from the addition of USEC-generated cylinders would be the same as that for management of DOE-generated cylinders described in Section 5.2.9. Storage space for the USEC cylinders is already present at the sites. If transfer facilities were built for cylinder preparation, the land use requirements would be the same as those for the DOE-generated cylinders only described in Section 5.2.9, because the facility operational period would increase, not the facility size. The land use required for a conversion facility would be the same as that for management of DOE-generated cylinders described in Section 5.6.9, because the facility size would remain the same.

The increase in land use requirements for disposal facilities to accommodate the USEC-generated cylinders would range from 8 to 116 acres (3 to 46 ha). The total land use requirement for disposal of DOE- and USEC-generated cylinders combined would range from 36 to 587 acres (14 to 230 ha), constituting a moderate to large potential land use impact.

6.3.6.10 Cultural Resources

For the disposal alternative, impacts to cultural resources would be unlikely at the current storage sites, because all activities would take place on previously developed land, and cultural impacts at a conversion or disposal facility would depend on the location of the facility.

6.3.6.11 Environmental Justice

The impacts to environmental justice would be the same as those for the DOE-generated cylinders only under the disposal alternative discussed in Section 5.6.11.

6.3.7 Preferred Alternative

DOE's preferred alternative is to begin conversion of the depleted UF_6 inventory, including USEC-generated cylinders, as soon as possible, either to uranium oxide, uranium metal, or a combination of both, while allowing for use of as much of this inventory as possible. As explained in Section 5.7, some portion of the inventory would probably require long-term storage as oxide, and for use, it could be in the form of either uranium oxide or uranium metal. To analyze the impacts of the preferred alternative as detailed in Section 5.7, a representative combination strategy involving 25% use as oxide, 25% use as metal, and 50% long-term storage as oxide was evaluated. Estimates of the impacts taken from parametric analyses of facilities with capacities ranging from 25% to 100% (presented in Appendix K) were added as appropriate to estimate the total impacts.

In practice, the addition of the USEC cylinders could be managed in a variety of ways. For example, facilities could be increased in size or operated longer to accommodate the additional inventory (as was assumed for the assessment of the potential impacts from the management of USEC-generated cylinders detailed in Sections 6.3.1 through 6.3.6). To remain consistent with the assumptions for the USEC-generated cylinders used in Sections 6.3.1 through 6.3.6, the analysis conducted for this section assumed that the facilities would operate longer to process the additional inventory. (For example, a 75%-capacity conversion to oxide facility would operate about 6 years longer, for a total of 26 years, to process 75% of the USEC-generated cylinders; a 25%-capacity conversion to metal facility would operate about 6 years longer, to process 25% of the USEC-generated cylinders.) The results of the analyses detailed in Sections 6.3.1 through 6.3.6 were incorporated and modified when possible to estimate the combined impacts when both the DOE- and USEC-generated cylinders are considered under the preferred alternative. For example, the impacts that would result from continued storage would be the same as those presented under the long-term storage as UF_6 alternative that considers USEC cylinders (Section 6.3.2).

6.3.7.1 Human Health and Safety

6.3.7.1.1 Normal Facility Operations

Under the preferred alternative, the management of USEC-generated cylinders would increase the levels of exposure of workers and members of the public to radiation and chemicals when compared with the management of DOE-generated cylinders only presented in Chapter 5. For involved workers, the increased radiation exposure could result in a maximum of 1 LCF in addition to the potential 1 to 2 LCFs estimated for the management of DOE-generated cylinders. Thus, the estimated total, when both DOE- and USEC-generated cylinders are considered, would range from 2 to 3 LCFs. For noninvolved workers and members of the public, the increased levels of exposure would not be large enough to cause appreciable increases in the potential health impacts under the preferred alternative discussed in Chapter 5.

Workers. Under the preferred alternative, the management of the additional USEC cylinders (including continued cylinder storage, cylinder preparation, conversion to both uranium oxide and uranium metal, empty cylinder treatment, manufacture of oxide- and metal-shielded casks, and long-term storage of oxide) was estimated to increase the total dose to involved workers by about 30%, resulting in a maximum of 1 additional LCF. The total number of health effects among involved workers (when both DOE- and USEC-generated cylinders are considered) would range from 2 to 3 LCFs over the duration of the program. (The dose to noninvolved workers would remain negligible when compared with the involved worker dose.)

In general, the average annual radiation dose to individual workers associated with management of the additional USEC cylinders would be the same or less than that for DOE-generated cylinders reported on in Chapter 5 (i.e., well within applicable standards) because (1) at the current storage sites and a long-term storage facility, additional cylinder yard workers would be used instead of having the same individuals conduct extra activities and (2) conversion and manufacturing facilities would be smaller than the full-scale facilities and would thus require fewer worker activities.

Increased exposure to chemicals would not be expected to increase health impacts on involved or noninvolved workers; the total estimated hazard indices (when both DOE- and USEC-generated cylinders are considered) would be less than 0.002 for noninvolved workers at all three current storage sites, a conversion facility, a manufacturing facility, or a consolidated storage facility.

General Public. Although the exposure of the public to radiation and chemicals would increase by about 30%, the overall potential impacts to members of the general public during normal operations would be the same as those for the management of DOE-generated cylinders only described in Section 5.7.1.1: all exposures would be within applicable public health standards, and no LCFs from radiation exposures and no adverse effects from chemical exposures would be expected to occur among members of the general public near the three current storage sites, a conversion facility, a manufacturing facility, or a consolidated long-term storage facility, when the management of additional USEC cylinders is considered.

At the current storage sites, potential public exposure to radiation and chemicals released from the sites would be exactly the same as that under the long-term storage as UF_6 alternative described in Section 6.3.2.1.1.

At conversion, manufacturing, and long-term storage facilities, the total exposure of the public in the vicinity of these facilities to airborne radiation and chemicals would increase by approximately 30% as a result of the processing of USEC-generated cylinders. However, total exposure levels would remain well within standards and below levels expected to cause any adverse health effects among the public.

6.3.7.1.2 Facility Accidents

Physical Hazards (On-the Job Injuries and Fatalities). Overall, on-the-job injuries and fatalities under the preferred alternative as presented in Section 5.7.2.2 and Table 5.11 would be expected to increase by about 30%. This percentage would represent an increase of about 700 to 990 injuries, for a total range of 2,900 to 4,100 injuries under the preferred alternative. The estimated fatalities would increase by about 1, to a total range of 4 to 5.

Accidents Involving Releases of Radiation or Chemicals. The assessment of impacts from these accidents would remain the same as previously that under the preferred alternative discussed in Section 5.7.2.1.

6.3.7.2 Transportation

The management of the USEC-generated cylinders would result in an increase of approximately 30% in the total number of shipments of UF_6 cylinders, uranium oxide, uranium metal, ammonia, anhydrous HF (if produced), CaF_2 (if produced), oxide- and metal-shielded casks, and waste materials. For normal (incident-free) transportation operations, these additional shipments would increase exposure to overall external radiation and vehicle exhaust emissions by about 30%. However, no additional adverse health effects would be expected among workers and the public during normal transportation activities when shipment of both DOE- and USEC-generated cylinders and associated materials is considered.

The 30% increase in the total number of shipments would increase the estimated numbers of fatalities due to truck and rail accidents (not involving releases of radioactive or hazardous materials) from the numbers presented in Section 5.7.3. The estimated number of fatalities from truck shipments would increase from 4 to 5. The estimated number of fatalities from rail shipments would increase from 1 to 2 over the duration of the program.

The consequences of severe traffic accidents involving releases of radiation or chemicals would be the same as those for the shipment of DOE-generated cylinders and associated materials described in Section 5.7.3, because the shipment sizes would not change. The annual probability of severe accidents occurring also would be the same as that discussed in Section 5.7.3, although the total probability of a severe accident would increase by about 30% as shipments continued for an additional 6 years.

6.3.7.3 Air Quality

At the current storage sites, potential impacts to air quality would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.3.

As stated in Section 5.7.4, under the preferred alternative, during the construction and operation of conversion, long-term storage, and manufacturing facilities designed to handle less than 100% of the inventory, pollutant emissions would remain within standards.

6.3.7.4 Water and Soil

At the current storage sites, potential impacts to water and soil would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.4.

Potential surface water, groundwater, and soil quality impacts at conversion, long-term storage, and manufacturing facilities would be site-dependent. On the basis of an evaluation of representative and generic sites, contaminant concentrations would be expected to remain within guideline levels.

The consideration of long-term storage of USEC-generated cylinders would result in increased excavation requirements. Additional excavation volumes would range from 10,000 to 200,000 yd^3 (7,600 to 150,000 m^3). The total required excavation volume would range from 51,000 to 1.3 million yd^3 (39,000 to 1.0 million m^3).

6.3.7.5 Socioeconomics

At the current storage sites, socioeconomic impacts would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.5.

The annual socioeconomic impacts from operating conversion to oxide and conversion to metal facilities under the preferred alternative would be the same as those estimated for the DOE-generated cylinders only in Section 5.7.5, but the period of operation would be extended by about 6 years. Socioeconomic impacts during construction would not change for the conversion facilities.

For the long-term storage as oxide component of the preferred alternative, construction and operations would be extended by 6 years as a result of the addition of the USEC-generated cylinders. The peak year construction jobs and income would not change from those stated in Table 2.4 for the preferred alternative (that is, 60–210 direct jobs, $3–10 million direct income). It is estimated that additional operational activities due to the USEC-generated cylinders would create from 9 to 11 direct jobs per year and up to $1 million in additional direct income. Thus, the total operational socioeconomic impacts from the DOE- and USEC-generated cylinders combined would be expected to range from 39 to 46 direct jobs per year and from $3 to $4 million in direct income per year. The values are in ranges to allow for the form of the oxide and the location used for storage (buildings, vaults, or a mine).

6.3.7.6 Ecology

The continued cylinder storage and preparation activities associated with management of the USEC-generated cylinders at the current storage sites would not result in additional impacts to ecological resources. Concentrations of uranium in soil, groundwater, and surface water would remain well below benchmark values for toxic and radiological effects. In addition, construction activities would take place on previously disturbed areas (i.e., existing yards) and would have no ecological impacts. Habitat losses due to conversion and manufacturing facilities would not change from those presented in Section 5.7.7.

At a long-term storage facility, the addition of the USEC-generated cylinders would increase the land use requirement by up to about 25% (see Section 5.7.7), from about 49 acres (20 ha) to 61 acres (25 ha). The result would be additional habitat loss, but this loss would still represent only a moderate potential impact to vegetation and wildlife.

6.3.7.7 Waste Management

At the current storage sites, potential impacts on waste management would be identical to those under the long-term storage as UF_6 alternative discussed in Section 6.3.2.7.

At uranium oxide and uranium metal conversion facilities, inclusion of the USEC-generated cylinders could increase the amount of CaF_2 and MgF_2 requiring disposal as LLW by about 30%. However, this increase would not change the overall assessment of impacts on waste management; disposal of the LLW would still have a moderate impact on nationwide LLW management (assuming these wastes would be considered DOE wastes).

At long-term storage and manufacturing facilities, impacts to waste management would generally be negligible, as described in Section 5.7.8. The operation of these facilities for an additional 6 years to process USEC-generated cylinders would not appreciably change waste management impacts.

The generation of waste for all components under the preferred alternative (when both DOE- and USEC-generated cylinders are considered) would have negligible to moderate impacts when considered in terms of national and regional waste management capabilities.

6.3.7.8 Resource Requirements

Under the preferred alternative, when the USEC cylinders are considered, adverse effects on local, regional, or national availability of materials would not be expected.

6.3.7.9 Land Use

No change in land use would occur at the current storage sites under the preferred alternative described in Section 5.7.7 when the USEC cylinders are considered. Storage space for the cylinders is already present at the sites. If transfer facilities were built for cylinder preparation, the land use requirements would be the same as those for the DOE-generated cylinders only described in Section 5.7.7, because the facility operational period would increase, not the facility size.

Land use requirements at conversion and manufacturing facilities would not change from those presented in Section 5.7.6, because the length of operations at these facilities would be increased to accommodate the USEC cylinders; sizes of the facilities would not be increased.

For the long-term storage component of the preferred alternative, the addition of the USEC-generated cylinders would increase the land use requirement by about 25% (Section 5.7.7), from about 49 acres (20 ha) to 61 acres (25 ha). This increase would still represent only a moderate potential land use impact.

6.3.7.10 Cultural Resources

The impacts to cultural resources would be the same as those for the DOE-generated cylinders under the preferred alternative discussed in Section 5.7.11.

6.3.7.11 Environmental Justice

The impacts to environmental justice would be the same as those for the DOE-generated cylinders under the preferred alternative discussed in Section 5.7.11.

6.3.8 Cumulative Impacts

This section addresses whether the consideration of the additional USEC-generated cylinders would increase the impacts of depleted UF_6 management activities sufficiently to change the cumulative impacts evaluation presented in Section 5.8.

Inclusion of the USEC-generated cylinders would increase the number of cylinders managed by DOE at the Paducah site by 42% and at the Portsmouth site by 22%. Activities at the K-25 site would be unaffected. Consequently, the duration of continued cylinder storage and preparation activities at the Paducah and Portsmouth sites would be extended by about 6 years, from 2028 through 2034.

At the Paducah site, the increased inventory would generally result in a 42% increase in the collective population dose to the involved workers and to the public from continued cylinder storage and preparation activities, as reported on in Table 5.12. However, this increase in radiological exposure would not significantly affect the estimated number of cumulative health effects at the Paducah site. The overall cumulative impacts to workers and the public would be unaffected by the increase in the inventory because of rounding effects and the fact that estimated health effects (e.g., LCFs) are presented as whole numbers. Similarly, although transportation requirements and resource and infrastructure requirements would increase, this increase would not significantly change the cumulative impacts from those presented in Table 5.12. Air quality standards at the Paducah site would not be exceeded, nor would groundwater quality impacts change from those estimated for the DOE-generated cylinders alone. (See Sections 6.3.1.3, 6.3.1.4, 6.3.2.3, and 6.3.2.4.)

At the Portsmouth site, the increased inventory would generally result in a 22% increase in the collective population dose to the involved workers and to the public from continued cylinder storage and preparation activities, as reported on in Table 5.13. However, this increase in radiological exposure would not significantly affect the estimated number of cumulative health effects at the Portsmouth site. The overall cumulative impacts to workers and the public would be unaffected by the increase in the inventory because of rounding effects and the fact that estimated health effects (e.g., LCFs) are presented as whole numbers. Although transportation requirements and resource and infrastructure requirements would increase, this increase would not significantly change the cumulative impacts from those presented in Table 5.13. Air quality standards at the Portsmouth site would not be exceeded, nor would groundwater quality impacts change from those estimated for the DOE-generated cylinders alone. (See Sections 6.3.1.3, 6.3.1.4, 6.3.2.3, and 6.3.2.4.)

7 ENVIRONMENTAL, OCCUPATIONAL SAFETY, AND HEALTH PERMITS AND COMPLIANCE REQUIREMENTS

The major laws, regulations, executive orders, and compliance instruments that would apply to activities of the Depleted Uranium Hexafluoride Management Program under the no action and other alternatives are identified below. Various federal environmental statutes impose environmental protection and compliance requirements upon DOE. Further, those authorities have been assessed to determine which state and local environmental authorities are also applicable because they are delegated to the states for enforcement or implementation under federal law. It is DOE policy to conduct its operations in an environmentally safe manner in compliance with all applicable statutes, regulations, and standards. Although this chapter does not address pending legislation or regulations that may become effective in the future, DOE recognizes that the regulatory environment is rapidly changing and that the construction and operation of any future depleted UF_6 management alternative must be conducted in compliance with the applicable statutes, regulations, and standards in effect at the time.

The *Atomic Energy Act* of 1954 (42 *United States Code* [USC] 2011 et seq.) authorizes the DOE to establish standards to protect health or minimize dangers to life or property for its facilities and operations. The DOE has established an extensive system of standards and requirements through DOE Orders to ensure safe operation of its facilities. Executive Order 12088, "Federal Compliance with Pollution Control Standards," requires federal agencies — including DOE — to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the *Clean Air Act*, *Clean Water Act*, *Safe Drinking Water Act*, *Resource Conservation and Recovery Act*, and *Toxic Substances Control Act*.

In addition to those in Executive Order 12088, other environmental, occupational safety, and health permit and compliance requirements might also apply to activities under the PEIS alternatives. Depending on the locale chosen for the new activity, particularly the siting, construction, and operation of new facilities, these potential requirements might include the following:

- *Clean Air Act Amendments* (CAAA) of 1990 (Public Law 101-549, 104 Statute 2684, November 15, 1990);
- *Federal Facilities Compliance Act* (FFCA) of 1992 (Public Law 120-386, 106 Statute 1505, October 6, 1992);
- *Atomic Energy Act* of 1954;
- *Low-Level Radioactive Waste Policy Act*;

- *Emergency Planning and Community Right-to-Know Act* of 1986 (as extended to federal facilities by Executive Order 12856, August 3, 1993);
- *Endangered Species Act*, as amended;
- *Migratory Bird Treaty Act*, as amended;
- *Bald and Golden Eagle Protection Act*, as amended;
- *National Historic Preservation Act* of 1966, as amended;
- *Archaeological and Historic Preservation Act*;
- *American Indian Religious Freedom Act* of 1978;
- *Wild and Scenic Rivers Act;*
- *Farmland Protection Policy Act;*
- *Soil and Water Conservation Act* of 1977; and
- Executive Order 12898 — "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations."

DOE also entered into a Consent Order with the Department of Environment and Conservation of the State of Tennessee with respect to the management of the depleted UF_6 stored at the K-25 site. DOE has agreed that if it chooses any action alternative as the outcome of this PEIS, it shall, subject to appropriate NEPA review, either remove all known depleted UF_6 cylinders from K-25 or complete the conversion of their contents by December 31, 2009.

DOE has entered into an agreement with the Ohio EPA for the management of the depleted uranium stored at the Portsmouth site. This agreement, dated February 24, 1998, is entitled "Ohio EPA Director's Final Findings and Orders" (DFF&O) and is the result of the State's Notice of Violation issued against DOE. The DFF&O outlines the management, surveillance and maintenance activities, inspection requirements, and other requirements for the depleted UF_6 storage yards and cylinders owned by DOE at the Portsmouth site.

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DOE/EIS-0269

FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR ALTERNATIVE STRATEGIES FOR THE LONG-TERM MANAGEMENT AND USE OF DEPLETED URANIUM HEXAFLUORIDE

Volume 2: Appendices

April 1999

U.S. Department of Energy
Office of Nuclear Energy, Science and Technology

COVER SHEET

RESPONSIBLE FEDERAL AGENCY: U.S. Department of Energy (DOE)

TITLE: Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride (DOE/EIS-0269)

CONTACT: For further information on this Programmatic Environmental Impact Statement (PEIS), call or contact:

Scott E. Harlow*
Office of Nuclear Facilities Management (NE-40)
Office of Nuclear Energy, Science and Technology
U.S. Department of Energy
19901 Germantown Road
Germantown, MD 20874
301-903-3352

For general information on the DOE NEPA process, call 1-800-472-2756 to leave a message or contact:

Carol Borgstrom, Director
Office of NEPA Policy and Assistance (EH-42)
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585
202-586-4600

ABSTRACT: This PEIS assesses the potential impacts of alternative management strategies for depleted uranium hexafluoride (UF_6) currently stored at three DOE sites: Paducah site near Paducah, Kentucky; Portsmouth site near Portsmouth, Ohio; and K-25 site on the Oak Ridge Reservation, Oak Ridge, Tennessee. The alternatives analyzed in the PEIS include no action, long-term storage as UF_6, long-term storage as uranium oxide, use as uranium oxide, use as uranium metal, and disposal. DOE's preferred alternative is to begin conversion of the depleted UF_6 inventory as soon as possible, either to uranium oxide, uranium metal, or a combination of both, while allowing for use of as much of this inventory as possible.

* Vertical lines in the right margin of this cover sheet and the appendixes indicate changes that have been added after the public comment period.

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FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

OVERALL CONTENTS (Cont.)

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CONTENTS — VOLUME 2 (Cont.)

ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS

In this document, units of measure are presented with the English unit first, followed in most cases by the metric equivalent in parentheses; if the measurement was originally made in metric units, the values were not converted back to English units. In tables, the data are expressed in one unit only. The following table lists the appropriate equivalents for English and metric units.

Multiply	By	To Obtain
English/Metric Equivalents		
acres	0.4047	hectares (ha)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
degrees Fahrenheit (°F) -32	0.5555	degrees Celsius (°C)
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
gallons (gal)	0.003785	cubic meters (m^3)
inches (in.)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
short tons (tons)	907.2	kilograms (kg)
short tons (tons)	0.9072	metric tons (t)
square feet (ft^2)	0.09290	square meters (m^2)
square yards (yd^2)	0.8361	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
yards (yd)	0.9144	meters (m)
Metric/English Equivalents		
centimeters (cm)	0.3937	inches (in.)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters (m^3)	1.308	cubic yards (yd^3)
cubic meters (m^3)	264.2	gallons (gal)
degrees Celsius (°C) +17.78	1.8	degrees Fahrenheit (°F)
hectares (ha)	2.471	acres
kilograms (kg)	2.205	pounds (lb)
kilograms (kg)	0.001102	short tons (tons)
kilometers (km)	0.6214	miles (mi)
liters (L)	0.2642	gallons (gal)
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
metric tons (t)	1.102	short tons (tons)
square kilometers (km^2)	0.3861	square miles (mi^2)
square meters (m^2)	10.76	square feet (ft^2)
square meters (m^2)	1.196	square yards (yd^2)

APPENDIX A:

CHEMICAL FORMS AND PROPERTIES OF URANIUM

CONTENTS (APPENDIX A)

TABLE

FIGURE

NOTATION (APPENDIX A)

The following is a list of acronyms and abbreviations, including units of measure, used in this appendix.

ACRONYMS AND ABBREVIATIONS

General

DOE	U.S. Department of Energy
PEIS	programmatic environmental impact statement

Chemicals

BrF_3	bromine fluoride
Cl_2	chlorine
F_2	fluorine
HF	hydrogen fluoride; hydrofluoric acid
HNO_3	nitric acid
H_2O	water
NH_3	ammonia
O_2	oxygen
S	sulfur
Se	selenium
TCE	trichloroethylene
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UH_3	uranium hydride
UO_2	uranium dioxide
UO_2F_2	uranyl fluoride
UO_3	uranium trioxide
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

atm	atmosphere(s)
°C	degrees Celsius
°F	degrees Fahrenheit
cm^3	cubic centimeter(s)
g	gram(s)
mPa	millipascal(s)
psia	pounds per square inch absolute

APPENDIX A:

CHEMICAL FORMS AND PROPERTIES OF URANIUM

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites near Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix describes the properties of the chemical forms of uranium that are relevant to the analysis in the PEIS.

Most depleted uranium in the United States is currently stored as solid UF_6 in steel cylinders that have a wall thickness of at least 5/16 in. and are located outdoors. Although UF_6 can be handled and stored safely in a well-managed industrial environment, other uranium compounds or uranium metal may be more appropriate for long-term storage, use, or permanent disposal. Potential compounds other than UF_6 include triuranium octaoxide (U_3O_8) and uranium dioxide (UO_2).

A.1 PHYSICAL PROPERTIES

The physical properties of the pertinent chemical forms of uranium are shown in Table A.1.

A.1.1 Uranium Hexafluoride

Uranium hexafluoride (UF_6) at ambient conditions is a volatile, white, crystalline solid. Solid UF_6 is readily transformed into the gaseous or liquid states by the application of heat. All three phases — solid, liquid, and gas — coexist at 147°F (64°C) (the triple point). Only the gaseous phase exists above 446°F (230°C), the critical temperature, at which the critical pressure is 45.5 atm (4.61 mPa). The vapor pressure above the solid reaches 1 atm (0.1 mPa) at 133°F (56°C), the sublimation temperature.

Figure A.1 is the phase diagram covering the range of conditions usually encountered in working with UF_6. It shows the correlation of pressure and temperature with the physical state of UF_6. The triple point occurs at 22 pounds per square inch, absolute (psia) and 147°F (64°C). These are the only conditions at which all three states — liquid, solid, and gas — can exist in equilibrium. If the temperature or pressure is greater than at the triple point, there will only be gas or liquid.

A large decrease in UF_6 density occurs when UF_6 changes from the solid to the liquid state, which results in a large increase in volume. The thermal expansion of the liquid with increasing

TABLE A.1 Physical Properties of Pertinent Uranium Compounds

		Density (g/cm^3)		
Compound	Melting Point (°C)	Crystal/ Particle	Bulk[a]	Solubility in Water at Ambient Temperature
UF_6	64.1	5.1	5.1	Decomposes to UO_2F_2
UF_4	960 ± 5	6.7	2.0 – 4.5	Very slightly soluble
U_3O_8	Decomposes to UO_2 at 1,300	8.30	1.5 – 4.0	Insoluble
UO_2	2,878 ± 20	10.96	2.0 – 5.0	Insoluble
Uranium metal	1,132	19.05	19	Insoluble

[a] Bulk densities of UF_4, U_3O_8, and UO_2 are highly variable, depending on the production process and the properties of the starting uranium compounds.

Notation: UF_4 = uranium tetrafluoride; UF_6 = uranium hexafluoride; UO_2 = uranium dioxide; UO_2F_2 = uranyl fluoride; U_3O_8 = triuranium octaoxide.

temperature is also high. Therefore, it is important to maintain control of the total mass and physical state of UF_6 throughout an operational cycle. To avoid hydraulic rupture, when items with restricted volumes, such as traps and containers, are filled with UF_6, full allowance must be made for the volume changes that will arise over the working temperature range to which the vessels will be subjected.

For UF_6 to be handled as a liquid, the pressure must be in excess of 0.15 mPa (1.5 atm) and the temperature above 147°F (64°C) because the sublimation temperature lies below the triple point. Thus, any process using liquid UF_6 is above atmospheric pressure and is subject to a potential leakage of UF_6 to the environment, with vapor loss and cooling occurring simultaneously. Solidification occurs exothermically when the pressure falls below 1.5 atm (0.15 mPa). Thus, if a cylinder heated above the triple point is breached, a rapid outflow of the UF_6 occurs until the pressure drops sufficiently to start the solidification process. The rate of outflow then decreases but continues until the contents cool to about 133°F (56°C), which is the atmospheric sublimation temperature. Some release of material may continue, depending on the type and location of the breach.

UF_6 is hygroscopic (i.e., moisture-retaining) and, in contact with water (H_2O), will decompose immediately to uranyl fluoride (UO_2F_2). When heated to decomposition, UF_6 emits toxic fluoride fumes.

A.1.2 Uranyl Fluoride (Uranium Oxyfluoride)

Uranyl fluoride (UO_2F_2) is an intermediate in the conversion of UF_6 to an uranium oxide or metal form and is a direct product of the reaction of UF_6 with moisture in the air. It is very soluble

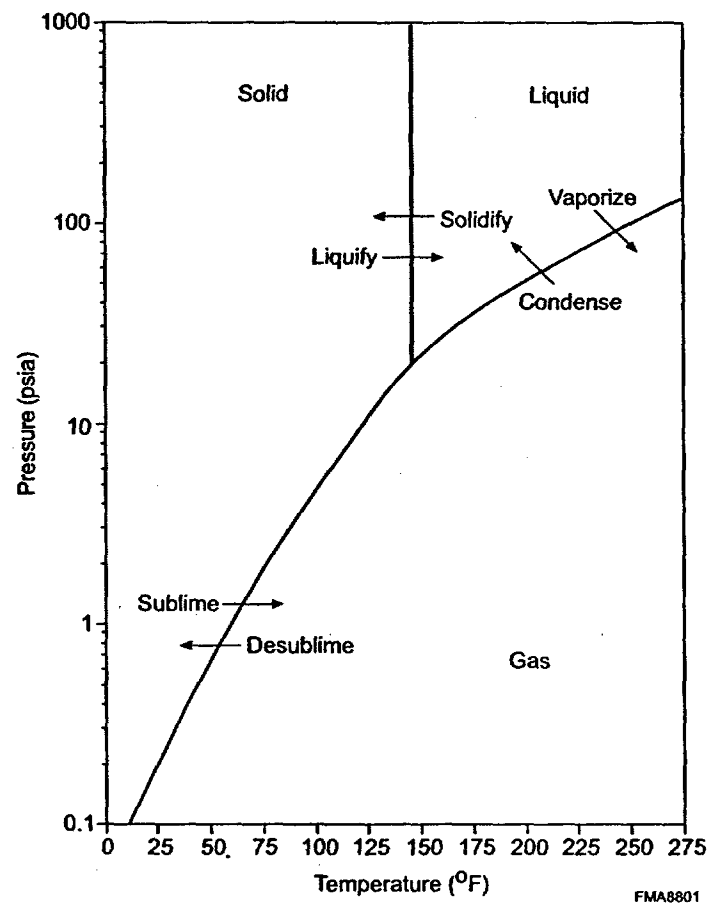

FIGURE A.1 Uranium Hexafluoride Phase Diagram

in water. Uranyl fluoride also is hygroscopic and changes in color from brilliant orange to yellow after reacting with water. Uranyl fluoride is reported to be stable in air to 570°F (300°C), above which slow decomposition to U_3O_8 occurs. When heated to decomposition, UO_2F_2 emits toxic fluoride fumes.

A.1.3 Uranium Tetrafluoride

Uranium tetrafluoride (UF_4) is a green crystalline solid that melts at about 1,760°F (960°C) and has an insignificant vapor pressure. It is very slightly soluble in water. It is generally an intermediate in the conversion of UF_6 to either uranium oxide (U_3O_8 or UO_2) or uranium metal. It is formed by the reaction of UF_6 with hydrogen gas in a vertical tube-type reactor or by the action of hydrogen fluoride (HF) on uranium dioxide. UF_4 can be readily converted to either uranium metal or uranium oxide. UF_4 is less stable than the uranium oxides and produces hydrofluoric acid in reaction with water; it is thus a less favorable form for long-term disposal.

A.1.4 Triuranium Octaoxide

Triuranium octaoxide (U_3O_8) occurs naturally as the olive-green-colored mineral pitchblende. U_3O_8 is readily produced from UF_6 and has potential long-term stability in a geologic environment. In the presence of oxygen (O_2), uranium dioxide (UO_2) and uranium trioxide (UO_3) are oxidized to U_3O_8. U_3O_8 can be made by three primary chemical conversion processes, involving either UF_4 or UO_2F_2 as intermediates. It is generally considered to be the more attractive form for disposal purposes because, under normal environmental conditions, U_3O_8 is one of the most kinetically and thermodynamically stable forms of uranium and also because it is the form of uranium found in nature.

A.1.5 Uranium Dioxide

Uranium dioxide (UO_2) is the form in which uranium is most commonly used as a nuclear reactor fuel. It is a stable ceramic that can be heated almost to its melting point, 5,212°F (2,878°C), without serious mechanical deterioration. It does not react with water to any significant level. At ambient temperatures, UO_2 will gradually convert to U_3O_8.

A.1.6 Uranium Metal

Uranium metal appears as a heavy, silvery white, malleable, ductile, softer-than-steel, metallic element. It is one of the densest materials known, being 1.6 times more dense than lead. Uranium metal is not as stable as U_3O_8 or UF_4 because it is subject to surface oxidation. It tarnishes in air, with the oxide film preventing further oxidation of massive metal at room temperature. Water attacks uranium metal slowly at room temperature and rapidly at higher temperatures. UO_2 and uranium hydride (UH_3) are formed while heat is evolved, and the metal swells and disintegrates.

A.2 CHEMICAL PROPERTIES

A.2.1 Uranium Hexafluoride

Uranium hexafluoride (UF_6) combines with water to form the soluble reaction products UO_2F_2 and HF. UF_6 is essentially inert to clean aluminum, steel, Monel, nickel, aluminum, bronze, copper, and Teflon™. Teflon is commonly used in the packing and cap gasket for cylinders storing depleted UF_6.

When released to the atmosphere, gaseous UF_6 combines with humidity to form a cloud of particulate UO_2F_2 and HF fumes. The reaction is very fast and is dependent on the availability of water vapor. Following a large-scale release of UF_6 in an open area, the dispersion is governed by meteorological conditions, and the plume could still contain unhydrolyzed material even after traveling a distance of several hundred meters. After hydrolysis, UO_2F_2 can be deposited as a finely divided solid, while HF remains as part of the gas plume.

In enclosed situations, the reaction products form a dense fog, reducing visibility for occupants of the area and hindering evacuation and emergency response. Fog can occur in unconfined areas if the humidity is high.

In a fire, the reaction of UF_6 with water is accelerated because of the increased UF_6 vapor pressure and the large quantities of water formed in combustion of organic materials or hydrocarbons. Reaction of liquid UF_6 with hydrocarbon vapors is extremely vigorous in flames, with formation of UF_4 and low-molecular-weight fluorinated compounds. More heat is generally released in these hydrocarbon interactions with UF_6 than in the corresponding reactions of hydrocarbons with oxygen.

A.2.2 Uranyl Fluoride

Uranyl fluoride (UO_2F_2) is a yellow hygroscopic solid that is very soluble in water. In accidental releases of UF_6, UO_2F_2 as a solid particulate compound may deposit on the ground over a large area.

A.2.3 Uranium Tetrafluoride

Uranium tetrafluoride (UF_4) reacts slowly with moisture at ambient temperature, forming UO_2 and HF, which are very corrosive.

A.2.4 Triuranium Octaoxide

Triuranium octaoxide (U_3O_8) has no hazardous chemical properties that are significant.

A.2.5 Uranium Dioxide

Uranium dioxide (UO_2) will ignite spontaneously in heated air and burn brilliantly. It will slowly convert to U_3O_8 in air at ambient temperature. Its stability in air can be improved by sintering the powder in hydrogen.

A.2.6 Uranium Metal

Uranium powder or chips will ignite spontaneously in air at ambient temperature. During storage, uranium ingots can form a pyrophoric surface because of reaction with air and moisture. Uranium metal will also react with water at ambient temperature, forming UO_2 and UH_3. The metal swells and disintegrates. Hydrogen gas can be released.

Solid uranium, either as chips or dust, is a very dangerous fire hazard when exposed to heat or flame. In addition, uranium metal can react violently with chlorine (Cl_2), fluorine (F_2), nitric acid (HNO_3), selenium (Se), sulfur (S), ammonia (NH_3), bromine fluoride (BrF_3), trichlorethylene (TCE), or nitryl fluoride and similar compounds.

APPENDIX B:

CYLINDER CORROSION AND MATERIAL LOSS FROM BREACHED CYLINDERS

CONTENTS (APPENDIX B)

TABLES

NOTATION (APPENDIX B)

The following is a list of acronyms and abbreviations, including units of measure, used in this appendix.

ACRONYMS AND ABBREVIATIONS

General

DOE	U.S. Department of Energy
PEIS	programmatic environmental impact statement
USEC	United States Enrichment Corporation

Chemicals

HF	hydrogen fluoride
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2F_2	uranyl fluoride

UNITS OF MEASURE

cm	centimeter(s)
in.	inch(es)
kg	kilogram(s)
lb	pound(s)
mil	mil(s)
psi	pound(s) per square inch
ton(s)	short ton(s)
yr	year(s)

APPENDIX B:

CYLINDER CORROSION AND MATERIAL LOSS FROM BREACHED CYLINDERS

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites near Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing cylinder corrosion and material loss from breached cylinders.

Depleted UF_6 has been stored in steel cylinders in outdoor yards at three DOE storage sites since the 1950s. Most cylinders have either a 10- or 14-ton (9- or 12-metric ton) capacity and a nominal wall thickness of 5/16 in. (0.79 cm, or 312.5 mil). The DOE-generated inventory consists of 46,422 cylinders, the oldest of which will have been in storage for about 45 years at the time of the PEIS record of decision and the youngest of which will have been in storage for about 5 years. United States Enrichment Corporation (USEC)-generated cylinders are considerably newer than the majority of DOE-generated cylinders.

An important criterion for the selection of a preferred management strategy for the depleted UF_6 cylinders is the expected condition of the cylinders throughout the time frames considered for various actions in the PEIS (i.e., 1999 through 2039). The condition of the cylinders is generally expressed in terms of remaining wall thickness (Nichols 1995), which determines whether the cylinders can be transported (thickness must be greater than 250 mil), pressurized in an autoclave (thickness must be greater than 200 mil), or lifted (thickness must be greater than 100 mil).[1] Cylinders that are breached (i.e., wall thickness at some part of the cylinder is 0) can produce environmental impacts by release of material.

All metals corrode to some extent when their surfaces are unprotected. In the past, depleted UF_6 cylinders have been stored in outdoor yards, and some groups of cylinders have been in contact with wet ground surfaces. An extensive cylinder maintenance program that began in the earlier 1990s has substantially improved storage conditions (e.g., paving of cylinder yards, restacking of cylinders onto concrete saddles, regular inspection of cylinders, and cylinder painting). However, accelerated corrosion has occurred on some cylinder surfaces, and eight breached cylinders have been identified

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[1] The wall thickness criteria were obtained from Hanrahan (1996). The transportation requirement is from the American National Standards Institute (ANSI 14.1, "American National Standards for Nuclear Materials — Packaging of Uranium Hexafluoride for Transport"); the pressurization standard is based on a requirement of the American Society of Mechanical Engineers ("Boiler and Pressure Vessel Code, Section VIII, Unfired Pressure Vessel") that pressure vessels pass a 100 psi rating; no source for the lift limit was cited.

in the inventory. The properties of depleted UF_6 in the solid form are such that release of material from breached cylinders occurs at a slow rate because the UF_6 degrades to a solid form of uranium that serves to "plug" the hole. To provide estimated impacts of continued storage for all or part of the cylinder inventory for an extended time period, it was necessary to estimate both the numbers of cylinders that might be breached and the amount of uranium compounds and hydrogen fluoride (HF) that would be expected to be released from any cylinder breaches that might occur in the future.

B.1 CYLINDER CORROSION MODELS

Efforts began in the mid 1970s and are ongoing to estimate the extent of corrosion of the depleted UF_6 cylinders and the numbers of breaches that might occur in the future. These studies are summarized in Nichols (1995). Generally, ultrasonic test measurements are used to estimate the current wall thickness at many locations on a single cylinder (current methods obtain 100,000 measurements for 0.1-in. [0.25-cm] squares on a single cylinder [Lyon 1996a]). In the simplest method for predicting breaches, the minimum wall thickness measurement is subtracted from a value assumed to be the initial wall thickness; this value is divided by the age of the cylinder to estimate an annual corrosion rate; the corrosion rate is then extrapolated forward from the cylinder age to arrive at an estimated year of breach. Because the ultrasonic tests are time-consuming and costly, only a small portion of the entire inventory has been measured. To estimate the numbers of breaches expected during various time intervals, several recent attempts have been made to extrapolate the results from the sample of cylinders measured to the entire inventory (Lyon 1995, 1996a-b, 1997; Nichols 1995; Rosen and Glaser 1996a-b).

Uncertainties associated with accurately estimating the expected number of breaches include the following:

- The sample of cylinders with ultrasonic test data available is not a random sample from the entire inventory of cylinders. Generally, cylinders showing signs of accelerated corrosion were chosen for ultrasonic testing. Therefore, basing the corrosion rate for the entire cylinder inventory on the ultrasonic test data may result in overestimation of potential breaching.

- The initial thickness of the cylinders is not known. Although the manufacturer-specified thickness for the most prevalent cylinder type is 312.5 mil, many of the cylinders actually had greater initial wall thicknesses. One estimate of the maximum initial wall thickness for the 5/16-in. (0.79-cm) cylinders is 345.5 mil, based on the nominal 312.5-mil thickness plus an American Society for Testing and Materials mill tolerance of 33 mil; however, estimates of up to 400-mil initial thickness have been made for some 5/16-in. (0.79-cm) cylinders at the Portsmouth site (Nichols 1995).

- Currently, it is not possible to reliably address the effects of past storage history on different cylinder inventories. Previously, some cylinders were stored under substandard conditions in which they were in prolonged contact with moisture. Improved storage conditions have undoubtedly reduced the corrosion rates. However, these changes have not been accounted for in the modeling studies because not enough data are available on corrosion rates under the improved storage conditions to support the predictive models.

In a more recent method used to predict numbers of breached cylinders over time (Lyon 1996b, 1997), the available ultrasonic test data were modeled using one to three functional forms (i.e., statistical equations) for predicting corrosion. (Corrosion is also referred to as penetration depth in Lyon 1996b.) Each statistical form of corrosion was assumed to be either normally or lognormally distributed. The three forms represent statistical methods that assume (1) the distribution of corrosion rates is constant with time or (2) the corrosion rates level off with time. For the modeling, the initial thickness of the cylinders was assumed to have a triangular distribution between 302.5 and 345.5 mil, with a most likely value of 330 mil.

B.2 BREACHED CYLINDERS AND MATERIAL LOSS

Before 1998, seven breached cylinders had been identified at the three storage locations: four at the K-25 site, two at the Portsmouth site, and one at the Paducah site. The first breached cylinders to be identified were those at the Portsmouth site. Investigation of these breached cylinders indicated that the initial damage occurred during stacking because of impact with an adjacent cylinder at the weld joint of the stiffening ring and the cylinder wall (Barber et al. 1991). The hole sizes increased over time due to moist air migrating into the cylinder and reacting with the UF_6 and iron. This reaction resulted in a dense plug of uranium tetrafluoride (UF_4) hydrates and various iron fluoride hydrates that prevented rapid loss of material from the cylinders. One breached cylinder that had been in storage for 13 years had an approximate hole size of 9 in. × 18 in. (23 cm × 46 cm); the mass of UF_6 lost from this cylinder was estimated to be between 17 and 109 lb (7.7 and 49 kg). The other breached cylinder had a hole 2 in. (5.1 cm) in diameter and had been in storage only 4 years; the mass of uranium lost from this cylinder was estimated to be less than 4 lb (1.8 kg).

Of the four breached cylinders identified at the K-25 site, two were concluded to have been damaged during handling in a manner similar to the breached cylinders at the Portsmouth site. However, external corrosion due to prolonged ground contact was concluded to be the cause of the other two breaches (Barber et al. 1994). The hole sizes in the four breached cylinders were 2 in. (5.1 cm) in diameter (cylinder stored for about 16 years), 6 in. (15 cm) in diameter (cylinder stored for about 28 years), 10 in. (25 cm) in diameter (cylinder stored for about 33 years), and 17 in. × 12 in. (43 cm × 30 cm) (cylinder stored for about 17 years). Because equipment to weigh the cylinders was not available at the K-25 site, the extent of material loss from the cylinders could not be determined.

The hole size of the breached cylinder identified at the Paducah site in 1992 was approximately 1/16 in. × 2 in. (0.16 cm × 5.1 cm); the cause of the breach was concluded to be damage during handling. The contents of the cylinder have been transferred to another cylinder.

In 1998, one additional breached cylinder occurred at the K-25 site during the course of cylinder maintenance operations (i.e., cylinder painting). Previous corrosion modeling had predicted that some additional cylinder breaches would be detected during such activities; see Table B.1. The breach occurred during steel grit blasting of the cylinder surface in preparation for painting. An as-fabricated weld defect was opened by the blast process. The cylinder management program includes provisions for patching newly identified breached cylinders to eliminate releases of material.

B.3 ESTIMATED NUMBER OF CYLINDER BREACHES AND MATERIAL LOSS USED FOR ANALYSIS

One of the strategies being used to maintain the cylinders is a painting program to mitigate external corrosion. It is estimated that the paint system currently in use will be effective for 12 years before significant maintenance or repainting would be needed (Pawel 1997). The painting program is therefore designed to eliminate further reduction in wall thickness on painted cylinders during the effective life of the paint. Furthermore, once painted, no additional wall thinning would occur as long as the paint was maintained.

For the no action alternative, the impacts of indefinite continued storage at the three sites were analyzed by estimating the number of expected cylinder breaches through 2039, assuming that the maintenance and painting program would be effective in controlling corrosion of cylinder surfaces. This is considered to be representative of the actual conditions that will occur at the three sites. To address the uncertainty associated with the effectiveness of painting and with future painting schedules, an analysis was also conducted that assumed that cylinder corrosion continued at historical rates (i.e., that improved storage conditions and cylinder painting had no effect on corrosion).

For the no action alternative analyses, corrosion of the cylinders was assumed to continue until cylinders were painted (painting estimated to be complete by 2009). Corrosion estimates through 2009 were based on modeling of corrosion that has occurred to date (Lyon 1996b, 1997). The possibility of initiating breaches during handling of the cylinders was incorporated into the breach estimates by using historical data regarding the approximate rates of such handling-initiated breaches that have occurred to date. (The rate assumed was 0.00014 breach per cylinder move; this value was based on five breaches that were initiated by handling damage and the estimated number of 50,000-cylinder moves during storage to date, plus an additional factor of 0.00004 to account for the possibility of a cylinder breaching during handling because it had been weakened from previous corrosion.) The number of cylinder breaches in the inventory at each site through 2039 was estimated

TABLE B.1 Estimated Number of Breaches and Releases from DOE-Generated Cylinders at the Paducah, Portsmouth, and K-25 Sites from 1999 through 2039, Assuming Control of External Corrosion by Painting[a]

	Paducah Site				Portsmouth Site				K-25 Site			
Year of Breach	Cylinder Inventory	Number of Breaches[b]	Number of Active Breaches[c]	HF Emissions[d] (kg/yr)	Cylinder Inventory	Number of Breaches[b]	Number of Active Breaches[c]	HF Emissions[d] (kg/yr)	Cylinder Inventory	Number of Breaches[b]	Number of Active Breaches[c]	HF Emissions[d] (kg/yr)
1999	28,351	2	2	4	13,388	0	0	0	4,683	1	1	2
2000	28,351	1	3	6	13,388	2	2	4	4,683	1	2	4
2001	28,351	1	4	8	13,388	0	2	4	4,683	0	2	4
2002	28,351	1	5	10	13,388	1	3	6	4,683	0	2	4
2003	28,351	2	5	10	13,388	0	3	6	4,683	0	1	2
2004	28,351	1	5	10	13,388	0	1	2	4,683	0	0	0
2005	28,351	0	4	8	13,388	1	2	4	4,683	0	0	0
2006	28,351	1	4	8	13,388	0	1	2	4,683	0	0	0
2007	28,351	1	3	6	13,388	0	1	2	4,683	0	0	0
2008	28,351	1	3	6	13,388	1	2	4	4,683	1	1	2
2009	28,351	1	4	8	13,388	0	1	2	4,683	0	1	2
2010	28,351	1	4	8	13,388	1	2	4	4,683	0	1	2
2011	28,351	0	3	6	13,388	0	2	4	4,683	1	2	4
2012	28,351	1	3	6	13,388	0	1	2	4,683	0	1	2
2013	28,351	1	3	6	13,388	1	2	4	4,683	0	1	2
2014	28,351	1	3	6	13,388	0	1	2	4,683	0	1	2
2015	28,351	0	3	6	13,388	0	1	2	4,683	0	0	0
2016	28,351	1	3	6	13,388	1	2	4	4,683	0	0	0
2017	28,351	1	3	6	13,388	0	1	2	4,683	0	0	0
2018	28,351	1	3	6	13,388	1	2	4	4,683	0	0	0
2019	28,351	1	4	8	13,388	0	2	4	4,683	0	0	0
2020	28,351	1	4	8	13,388	0	1	2	4,683	1	1	2
2021	28,351	0	3	6	13,388	1	2	4	4,683	0	1	2
2022	28,351	1	3	6	13,388	0	1	2	4,683	0	1	2
2023	28,351	1	3	6	13,388	0	1	2	4,683	0	1	2
2024	28,351	1	3	6	13,388	1	2	4	4,683	0	0	0
2025	28,351	0	3	6	13,388	0	1	2	4,683	0	0	0

TABLE B.1 (Cont.)

	Paducah Site				Portsmouth Site				K-25 Site			
Year of Breach	Cylinder Inventory	Number of Breaches[b]	Number of Active Breaches[c]	HF Emissions[d] (kg/yr)	Cylinder Inventory	Number of Breaches[b]	Number of Active Breaches[c]	HF Emissions[d] (kg/yr)	Cylinder Inventory	Number of Breaches[b]	Number of Active Breaches[c]	HF Emissions[d] (kg/yr)
2026	28,351	1	3	6	13,388	1	2	4	4,683	0	0	0
2027	28,351	1	3	6	13,388	0	2	4	4,683	0	0	0
2028	28,351	1	3	6	13,388	0	1	2	4,683	0	0	0
2029	28,351	1	4	8	13,388	1	2	4	4,683	1	1	2
2030	28,351	0	3	6	13,388	0	1	2	4,683	0	1	2
2031	28,351	1	3	6	13,388	0	1	2	4,683	0	1	2
2032	28,351	1	3	6	13,388	1	2	4	4,683	0	1	2
2033	28,351	1	3	6	13,388	0	1	2	4,683	0	0	0
2034	28,351	1	4	8	13,388	1	2	4	4,683	0	0	0
2035	28,351	0	3	6	13,388	0	2	4	4,683	0	0	0
2036	28,351	1	3	6	13,388	0	1	2	4,683	0	0	0
2037	28,351	1	3	6	13,388	1	2	4	4,683	0	0	0
2038	28,351	1	3	6	13,388	0	1	2	4,683	1	1	2
2039	28,351	1	4	8	13,388	0	1	2	4,683	0	1	2
Total (1999-2039)		**36**				**16**				**7**		

[a] PEIS analyses conducted for the period 1999 through 2039. Existing models also predicted one possible breach at each site for 1998, because of either handling (Paducah and Portsmouth) or corrosion (K-25).

[b] Estimates based on the assumption that a painting program would be effective in eliminating external corrosion by the year 2009. Breaches prior to 2009 were calculated as the sum of corrosion-initiated breaches for the proportion left unpainted in each year (based on external corrosion statistical model [Lyon 1996b, 1997]) plus the handling-initiated breaches. For 2009-2039, only handling-initiated breaches were assumed. The breaches were assumed to go undetected for 4 years; in practice, improved storage conditions and maintenance and inspection procedures should prevent any breaches from occurring or going undetected for long periods.

[c] Number of active breaches = sum of current-year breaches and previous-3-year breaches, based on 4-year inspection intervals. Annual uranium emissions (lb/yr) = number of active breaches in that year (1 lb per active breach per year).

[d] Annual HF emissions (kg/yr) = number of active breaches × 0.0055 kg per breached cylinder per day × 365 days per year.

as the number of cylinder moves times the handling breach rate, added to the estimated number of corrosion breaches for unpainted cylinders through 2008. The number of cylinder moves through 2039 was estimated from the painting and relocation schedule given in Parks (1997), assuming two moves per painted cylinder. The annual numbers of breaches in DOE-generated cylinders estimated for the three sites on the basis of these assumptions are given in Table B.1.

The potential impacts that would occur using more conservative (i.e., higher) breach assumptions were estimated by assuming that the historical corrosion rates would continue through the year 2039. This assumption could be applicable if it was found that the effectiveness of the paint was significantly less than 12 years. For this analysis, the method of Lyon (1996b, 1997) for predicting numbers of cylinder breaches due to external corrosion was used to estimate the number of breaches expected through the year 2039 for the three sites, assuming that the entire inventory would remain in storage at the current sites. The values used were the maximums of the predicted ranges for each year, as summarized by Parks (1997). Separate breach rates were estimated for the Paducah site C-745-G-yard and the K-25 site K-1006-K-yard because the worst historical storage conditions have occurred in these yards. This method is subject to the uncertainties discussed in Section B.1. By using the maximum result of the range for a number of assumptions regarding the form of distribution of the penetration depth, this method probably overestimates the actual number of cylinder breaches that would occur at each site through the year 2039.

The estimated number of cylinder breaches among DOE-generated cylinders from 1999 through 2039, based on the method of Lyon (1996b, 1997), is listed in Tables B.2 through B.4 for the three sites. No adjustment was made to the breach estimates given in these tables to account for handling-initiated breaches. Handling-initiated breaches were considered less likely for these cylinders because no credit was taken for corrosion protection from painting (i.e., it is likely that much less painting and maintenance would be taking place). In any case, the number of handling-initiated breaches would be minor in comparison with the predicted corrosion-initiated breaches.

The potential impacts of continued DOE-generated cylinder storage through 2028 for the action alternatives considered in this PEIS were estimated on the basis of the conservative corrosion-initiated breaches predicted with Lyon's method (Lyon 1996b, 1997). However, for the period 2009 through 2028, the estimated number of breaches was reduced by the proportion of inventory reduction occurring in each year.

The estimated "active" breaches in specific years at the three sites are also shown in Tables B.1 through B.4. These values take into account that under the given assumptions for the continued storage period, the minimum required inspection frequency is once every 4 years, although some cylinders are inspected more frequently (i.e., suspect cylinders with signs of extensive exterior corrosion are inspected annually). Therefore, to calculate active breaches, it was assumed that all breaches would go undetected for 4 years. The number of active breaches is the sum of the current-year breaches and the previous-3-year breaches.

TABLE B.2 Estimated Number of Breaches and Releases from DOE-Generated Cylinders at the Paducah Site from 1999 through 2039, Assuming Historical Corrosion Rates

	Breaches and Releases at G-Yard				Breaches and Releases at All Other Yards			
Year of Breach	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)
1999	5,733	1	1	2	22,618	0	0	0
2000	5,733	0	1	2	22,618	0	0	0
2001	5,733	1	2	4	22,618	0	0	0
2002	5,733	0	2	4	22,618	0	0	0
2003	5,733	1	2	4	22,618	1	1	2
2004	5,733	1	3	6	22,618	0	1	2
2005	5,733	1	3	6	22,618	0	1	2
2006	5,733	1	4	8	22,618	1	2	4
2007	5,733	2	5	10	22,618	1	2	4
2008	5,733	2	6	12	22,618	1	3	6
2009	5,733	2	7	14	22,618	1	4	8
2010	5,733	2	8	16	22,618	1	4	8
2011	5,733	3	9	18	22,618	1	4	8
2012	5,733	3	10	20	22,618	1	4	8
2013	5,733	3	11	22	22,618	1	4	8
2014	5,733	4	13	26	22,618	1	4	8
2015	5,733	4	14	28	22,618	1	4	8
2016	5,733	5	16	32	22,618	1	4	8
2017	5,733	5	18	36	22,618	2	5	10
2018	5,733	5	19	38	22,618	1	5	10
2019	5,733	6	21	42	22,618	2	6	12
2020	5,733	7	23	46	22,618	1	6	12
2021	5,733	7	25	50	22,618	2	6	12
2022	5,733	8	28	56	22,618	2	7	14
2023	5,733	8	30	60	22,618	3	8	16
2024	5,733	9	32	64	22,618	2	9	18
2025	5,733	10	35	70	22,618	3	10	20
2026	5,733	10	37	74	22,618	2	10	20
2027	5,733	11	40	80	22,618	3	10	20
2028	5,733	13	44	88	22,618	4	12	24
2029	5,733	13	47	94	22,618	3	12	24
2030	5,733	15	52	104	22,618	4	14	28
2031	5,733	17	58	116	22,618	4	15	30
2032	5,733	17	62	124	22,618	5	16	32
2033	5,733	19	68	137	22,618	4	17	34
2034	5,733	20	73	147	22,618	5	18	36

TABLE B.2 (Cont.)

	Breaches and Releases at G-Yard				Breaches and Releases at All Other Yards			
Year of Breach	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)
2035	5,733	21	77	155	22,618	5	19	38
2036	5,733	22	82	165	22,618	6	20	40
2037	5,733	23	86	173	22,618	6	22	44
2038	5,733	24	90	181	22,618	6	23	46
2039	5,733	25	94	189	22,618	6	24	48
Total (1999-2039)		**351**				**93**		
Total Breaches at Site				**444**				

[a] These estimates are conservative estimates used for assessing potential impacts based on an external corrosion statistical model (Lyon 1996b, 1997). The estimates were based on the assumption that historical corrosion rates would continue through 2039 (i.e., that corrosion would not have been eliminated by painting and maintenance). In practice, painting of cylinders, improved storage conditions, and maintenance and inspection procedures should prevent any breaches from occurring or from going undetected for long periods.

[b] Number of active breaches = sum of current-year breaches and previous-3-year breaches, based on 4-year inspection intervals. Annual uranium emissions (lb/yr) = number of active breaches in that year (1 lb per active breach per year).

[c] Annual HF emissions (kg/yr) = number of active breaches × 0.0055 kg per breached cylinder per day × 365 days per year.

TABLE B.3 Estimated Number of Breaches and Releases from DOE-Generated Cylinders at the Portsmouth Site from 1999 through 2039, Assuming Historical Corrosion Rates

Year of Breach	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)
1999	13,388	0	0	0
2000	13,388	1	1	2
2001	13,388	1	2	4
2002	13,388	0	2	4
2003	13,388	0	2	4
2004	13,388	1	2	4
2005	13,388	1	2	4
2006	13,388	1	3	6
2007	13,388	1	4	8
2008	13,388	1	4	8
2009	13,388	0	3	6
2010	13,388	1	3	6
2011	13,388	1	3	6
2012	13,388	0	2	4

TABLE B.3 (Cont.)

Year of Breach	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)
2013	13,388	1	3	6
2014	13,388	1	3	6
2015	13,388	1	3	6
2016	13,388	1	4	8
2017	13,388	2	5	10
2018	13,388	1	5	10
2019	13,388	1	5	10
2020	13,388	2	6	12
2021	13,388	1	5	10
2022	13,388	2	6	12
2023	13,388	2	7	14
2024	13,388	2	7	14
2025	13,388	2	8	16
2026	13,388	2	8	16
2027	13,388	2	8	16
2028	13,388	3	9	18
2029	13,388	3	10	20
2030	13,388	2	10	20
2031	13,388	3	11	22
2032	13,388	4	12	24
2033	13,388	3	12	24
2034	13,388	3	13	26
2035	13,388	4	14	28
2036	13,388	4	14	28
2037	13,388	4	15	30
2038	13,388	4	16	32
2039	13,388	5	17	34
Total (1999-2039)		74		
Total Breaches at Site		74		

[a] These estimates are conservative estimates used for assessing potential impacts based on an external corrosion statistical model (Lyon 1996b, 1997). The estimates were based on the assumption that historical corrosion rates would continue through 2039 (i.e., that corrosion would not have been eliminated by painting and maintenance). In practice, painting of cylinders, improved storage conditions, and maintenance and inspection procedures should prevent any breaches from occurring or from going undetected for long periods.

[b] Number of active breaches = sum of current-year breaches and previous-3-year breaches, based on 4-year inspection intervals. Annual uranium emissions (lb/yr) = number of active breaches in that year (1 lb per active breach per year).

[c] Annual HF emissions (kg/yr) = number of active breaches × 0.0055 kg per breached cylinder per day × 365 days per year.

TABLE B.4 Estimated Number of Breaches and Releases from DOE-Generated Cylinders at the K-25 Site from 1999 through 2039, Assuming Historical Corrosion Rates

	Breaches and Releases at K-Yard				Breaches and Releases at E-Yard and L-Yard			
Year of Breach	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)
1999	2,945	1	1	2	1,738	0	0	0
2000	2,945	0	1	2	1,738	0	0	0
2001	2,945	0	1	2	1,738	0	0	0
2002	2,945	0	1	2	1,738	0	0	0
2003	2,945	0	0	0	1,738	0	0	0
2004	2,945	0	0	0	1,738	0	0	0
2005	2,945	2	2	4	1,738	1	1	2
2006	2,945	1	3	6	1,738	1	2	4
2007	2,945	0	3	6	1,738	0	2	4
2008	2,945	2	5	10	1,738	0	2	4
2009	2,945	0	3	6	1,738	0	1	2
2010	2,945	1	3	6	1,738	0	0	0
2011	2,945	2	5	10	1,738	0	0	0
2012	2,945	2	5	10	1,738	0	0	0
2013	2,945	2	7	14	1,738	0	0	0
2014	2,945	2	8	16	1,738	1	1	2
2015	2,945	2	8	16	1,738	0	1	2
2016	2,945	2	8	16	1,738	1	2	4
2017	2,945	2	8	16	1,738	0	2	4
2018	2,945	3	9	18	1,738	0	1	2
2019	2,945	3	10	20	1,738	1	2	4
2020	2,945	4	12	24	1,738	1	2	4
2021	2,945	4	14	28	1,738	1	3	6
2022	2,945	4	15	30	1,738	1	4	8
2023	2,945	5	17	34	1,738	0	3	6
2024	2,945	6	19	38	1,738	1	3	6
2025	2,945	6	21	42	1,738	0	2	4
2026	2,945	7	24	48	1,738	0	1	2
2027	2,945	6	25	50	1,738	1	2	4
2028	2,945	7	26	52	1,738	1	2	4
2029	2,945	8	28	56	1,738	0	2	4
2030	2,945	9	30	60	1,738	1	3	6
2031	2,945	10	34	68	1,738	1	3	6
2032	2,945	8	35	70	1,738	1	3	6
2033	2,945	11	38	76	1,738	1	4	8
2034	2,945	11	40	80	1,738	1	4	8

TABLE B.4 (Cont.)

	Breaches and Releases at K-Yard				Breaches and Releases at E-Yard and L-Yard			
Year of Breach	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)	Cylinder Inventory	Number of Breaches[a]	Number of Active Breaches[b]	HF Emissions[c] (kg/yr)
2035	2,945	11	41	82	1,738	1	4	8
2036	2,945	12	45	90	1,738	1	4	8
2037	2,945	12	46	92	1,738	1	4	8
2038	2,945	12	47	94	1,738	1	4	8
2039	2,945	12	48	96	1,738	1	4	8
Total (1999-2039)		**192**				**21**		
Total Breaches at Site				**213**				

[a] These estimates are conservative estimates used for assessing potential impacts based on an external corrosion statistical model (Lyon 1996b, 1997). The estimates were based on the assumption that historical corrosion rates would continue through 2039 (i.e., that corrosion would not have been eliminated by painting and maintenance). In practice, painting of cylinders, improved storage conditions, and maintenance and inspection procedures should prevent any breaches from occurring or from going undetected for long periods.

[b] Number of active breaches = sum of current-year breaches and previous-3-year breaches, based on 4-year inspection intervals. Annual uranium emissions (lb/yr) = number of active breaches in that year (1 lb per active breach per year).

[c] Annual HF emissions (kg/yr) = number of active breaches × 0.0055 kg per breached cylinder per day × 365 days per year.

A reasonable estimate of material loss from breached cylinders was required to analyze the impacts of breached cylinders for the continued cylinder storage component of each alternative considered in this PEIS. For uranium, it was assumed that the amount lost would be similar to the amount lost from the cylinder at Portsmouth that had been in storage for 4 years at the time of breach identification. Therefore, the amount of uranium lost was assumed to be 4 lb (1.8 kg) per breached cylinder: 1 lb/yr (0.45 kg/yr) uranium per breached cylinder. It was assumed that uranium would be released as solid uranyl fluoride (UO_2F_2), which would be deposited on the ground, from where it could be transported as runoff to soil or surface water or infiltrate to groundwater.

The rate of HF loss from breached cylinders increases over time as the hole size increases. The time-dependent rate provided in Barber et al. (1994) was used to estimate the average daily HF emission rate that would be applicable over the assumed 4-year period that a breach could go undiscovered. An exponential equation for HF loss was used to estimate a value of 0.0055 kg per day HF emission per breached cylinder (Folga 1996a-b). Potential uranium and HF emissions from breached cylinders are summarized in Tables B.1 through B.4 for the Paducah, Portsmouth, and K-25 sites.

For analysis of continued storage (Appendix D), it was assumed that welded patches would be applied within about 1 week of any breach discovery and that no further uranium or HF leakage would occur after patch application.

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APPENDIX C:

ASSESSMENT METHODOLOGIES

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NOTATION (APPENDIX C)

The following is a list of acronyms and abbreviations, including units of measure, used in this appendix.

ACRONYMS AND ABBREVIATIONS

General

AIHA	American Industrial Hygiene Association
ALARA	as low as reasonably achievable
BEA	U.S. Bureau of Economic Analysis
BEMR	*The 1996 Baseline Environmental Management Report*
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERPG	Emergency Response Planning Guideline
HEPA	high-efficiency particulate air (filter)
HVAC	heating, ventilating, and air conditioning
ICRP	International Commission on Radiological Protection
INEL EIS	*Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*
IRIS	Integrated Risk Information System
ISCST	Industrial Source Complex Short Term model
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLMW	low-level mixed waste
LLW	low-level radioactive waste
LMES	Lockheed Martin Energy Systems, Inc.
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
NRC	U.S. Nuclear Regulatory Commission
ORR	Oak Ridge Reservation
OSHA	U.S. Occupational Safety and Health Administration
PEIS	programmatic environmental impact statement
PEL	permissible exposure limit
$PM_{2.5}$	particulate matter having a particle diameter equal to or less than 2.5 μm
PM_{10}	particulate matter having a particle diameter equal to or less than 10 μm
ROI	region of influence
SIC	Standard Industrial Classification

TEDE	total effective dose equivalent
WM PEIS	*Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*

Chemicals

CaF_2	calcium fluoride
HF	hydrogen fluoride
MgF_2	magnesium fluoride
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_2F_2	uranyl fluoride
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

cm	centimeter(s)	µg	microgram(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)	min	minute(s)
h	hour(s)	mrem	millirem(s)
kg	kilogram(s)	ppm	part(s) per million
km	kilometer(s)	rem	roentgen-equivalent man (men)
km^2	square kilometer(s)	s	second(s)
L	liter(s)	Sv	sievert(s)
lb	pound(s)	yr	year(s)

APPENDIX C:

ASSESSMENT METHODOLOGIES

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites near Paducah, Kentucky; Portsmouth, Ohio; and on the Oak Ridge Reservation in Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing the methodology used to assess the potential environmental impacts for continued cylinder storage, cylinder preparation, conversion options, long-term storage, manufacture and use, and disposal. The general methodology is explained, and special applications for specific options or alternatives are summarized. For several technical areas — such as air resources, human health, water resources, socioeconomics, and transportation — separate technical reports provide additional details regarding these methods.

C.1 AIR RESOURCES

The assessment of air quality impacts in the depleted UF_6 PEIS considered pollutant emissions under normal operating conditions. Atmospheric dispersion of pollutant emissions from construction, operation, and maintenance activities were estimated with conventional modeling techniques, i.e., U.S. Environmental Protection Agency (EPA) Industrial Source Complex Short Term (ISCST) model (EPA 1995b) and SCREEN3 model (EPA 1995a).

For the evaluation of continued storage, internal combustion emissions and fugitive dust emissions from the planned construction of new storage areas were assessed. Additionally, material loss from hypothetical cylinder breaches was assessed. Loss of any depleted UF_6 through corrosion of cylinders in the storage yards would occur slowly enough that the depleted UF_6 would react with atmospheric moisture while still in the cylinder. The pollutant of concern from atmospheric releases due to cylinder breaches is hydrogen fluoride (HF). Emissions from postulated breaches were modeled using the ISCST model.

Estimated emissions were taken from the engineering analysis report (Lawrence Livermore National Laboratory [LLNL] 1997). Emissions data were provided for construction of facilities and for normal operations of the conversion, cylinder preparation, long-term storage, manufacture and use, and disposal options.

Air concentrations of radionuclides due to the emission of radioactive materials were estimated with the GENII code (Napier et al. 1988). Emissions of hazardous chemicals and other pollutants were estimated with the ISCST code (EPA 1995b). Results from the ISCST and GENII codes for given conditions are in good agreement with each other. The hour-by-hour meteorological data from the three current storage sites show the range of air quality impacts that could be anticipated at the facility boundaries from the estimated emissions. For the Paducah and Portsmouth site-specific and representative analyses, the plant boundaries rather than the site perimeters were used (see Chapter 3). The SCREEN3 model (EPA 1995a) was used to determine the maximum impacts possible under worst-case meteorological conditions.

For impact analyses of representative environmental settings (i.e., analyses for the conversion and long-term storage options), the representative facility was assumed to be centered within a larger site (i.e., the plant boundaries of the three representative sites), and pollutant concentrations were estimated for the boundaries of that site. Screening modeling of construction emissions was used to estimate hourly pollutant concentrations under very conservative meteorological conditions at the boundary point that would be the shortest distance from the center of the facility. For impact analyses of generic environmental settings (i.e., analyses for the manufacture and use and disposal options), the pollutant concentrations at several distances from the center of the facility were estimated because of uncertainty regarding the size and location of the generic sites. Estimates at 2,460 ft (750 m) from the center of the generic facilities are comparable to the estimates for options based on representative environmental settings (i.e., conversion and long-term storage options using the three current storage sites as representative). The shortest distances from the centers of the representative sites to their boundaries range from 2,300 to 2,600 ft (700 to 800 m).

The radiological impacts under normal operational conditions would be long-term, cumulative impacts. Site-specific data (for facilities located at the existing cylinder storage sites) or representative long-term meteorological data (joint frequency data) were used to estimate air concentrations of the released radionuclides. For hazardous chemicals and other pollutants, short-term meteorological data were used because of the required regulatory compliance with short-term standards and different human health impact endpoints.

Additional meteorological data sets were used in the analyses of the disposal and manufacture and use options. The data sets were grouped into dry and wet environmental settings. The historical meteorological conditions for five actual "dry" locations in the southwestern United States and five actual "wet" locations in the central and southeastern United states were averaged to develop estimates for these generic environmental settings.

The type of data used for the air quality analysis included the following:

- On-site meteorological data — such as temperature, wind speed, and wind direction — and a description of the recording tower;
- Air quality data from the plant environs (state data); and
- State and federal ambient air quality standards.

Impacts relative to the ambient air quality standards for particulate matter with a particle diameter equal to or less than 2.5 µm ($PM_{2.5}$), announced by the EPA on July 17, 1997, were not estimated because the worst-case particulate emissions are likely to be coarse particulates (dust) emitted during construction, for which the PM_{10} (particulate matter with a particle diameter equal to or less than 10 µm) standards are more appropriate.

Complex terrain analysis was not required for SCREEN3 modeling. Also, to estimate air quality impacts at the facility perimeter and off the site, downwash calculations to determine the influence of on-site buildings were not needed.

Additional details on the analysis of air quality impacts are presented in Tschanz (1997).

C.2 WATER RESOURCES

For the depleted UF_6 PEIS, hydrological assessments were performed for all options for both surface water and groundwater. The assessment of water resources included evaluation of (1) existing hydrological environment for continued storage at the three current storage sites; (2) potential impacts of construction, operation, and accident scenarios for the cylinder preparation and conversion facility/storage options; and (3) potential impacts to the hydrological environment for hypothetical generic sites with respect to disposal and manufacture and use. For these generic options, two environmental settings were evaluated, a dry environment and a wet environment.

C.2.1 Continued Cylinder Storage

For the continued cylinder storage option, storage of depleted UF_6 cylinders would continue at each of the existing sites. A large number of cylinders containing depleted UF_6 are currently stored at the Paducah, Portsmouth, and K-25 sites. Because of their age, potential direct contact with the ground, and skirted ends (an extension of the cylinder walls to protect the cylinder valve from potential impact damage, which was used in a limited number of cylinder designs), many of these cylinders show signs of corrosion. Some instances of cylinder wall breach through corrosion have occurred, with subsequent exposure of depleted UF_6 to the environment (see Appendix B).

Unknown quantities (estimated to be small) of solid depleted UF_6, uranium tetrafluoride (UF_4), uranyl fluoride (UO_2F_2), and HF dissolved in water might come in contact with the material beneath a breached cylinder. For cylinders stored on concrete pads, the released material could be transported laterally by precipitation and surface runoff. If not collected or if the collection system failed, the transported material could gather in surface depressions or be swept into nearby surface drainages, potentially contaminating streams or other surface water bodies. Soluble forms could infiltrate the ground surface in areas of groundwater recharge and potentially contaminate underlying aquifers. The released material could also dissolve and infiltrate the surface and contaminate shallow groundwater adjacent to the storage area. The released material would act as a source of potential contamination until it was fully dissolved or remediated.

For impact analysis, each active breached cylinder was assumed to release 4 lb (1.8 kg) of uranium over a 4-year period. For each of the three sites, the yard with the most predicted breaches was used in the calculations (C-745-G yard [G-yard] at Paducah, K-1066-K yard [K-yard] at Oak Ridge, and a combination of the X-745-E yard [E-yard] and X-745-C [C-yard] at Portsmouth). Because more than one breach could be active at any one time, the maximum number of active breaches was estimated by using a moving 4-year sum of breaches (see Appendix B).

For continued storage of cylinders, existing conditions were evaluated for surface water and groundwater. Surface water conditions were derived from field measurements of water quality in appropriate drainages where data were available. If data were not available, the existing conditions were estimated using the solubility of the potential contaminants and dilution estimates for the surface water features.

The concentrations of uranium leaving the yards at the three current storage sites were estimated with a simple mass balance based on the area of the yard, the average annual precipitation, and the maximum number of active breached cylinders (Tomasko 1997b). This contaminated water was then assumed to flow over land to the nearest stream, where it would mix with initially clean water and become more dilute. Maximum concentrations in the receiving water were evaluated at the point of discharge from the yards; additional downstream mixing and dispersion were not considered.

To estimate groundwater quality downgradient of the storage yards, the maximum concentration at the water table was estimated by using a one-dimensional analytical solution to a governing partial differential equation that incorporates advection, dispersion, adsorption, and decay for a time-dependent, step-function source (Tomasko 1997a-b). For groundwater quality calculations, the contaminant source was assumed to have a maximum concentration equal to the maximum value in water leaving the storage yard with the most breached cylinders. All water leaving the yard was then assumed to infiltrate the surface and move vertically downward to the underlying groundwater aquifer. To provide conservative yet realistic estimates of groundwater concentrations, the source was modeled as a step-function having a duration equal to the full width of the half-maximum concentration value (approximately 20 years for each of the three sites). Additional details on the groundwater modeling are discussed in Tomasko (1997a-b).

C.2.2 Other Options

For the cylinder preparation, conversion, and storage options, physical impacts to surface water (i.e., changes in runoff and floodplain encroachment) and groundwater (i.e., changes in recharge, depth to groundwater, and direction of flow) were evaluated for construction, operations, and accident scenarios identified in the engineering analysis report (LLNL 1997).

Impacts to runoff were evaluated with a two-step procedure. First, the amount of land area was estimated that would be changed by installing paved lots and other low-permeability features, which would modify surface permeability (ease with which water infiltrates the ground surface). Decreases in surface permeability would lead to increases in runoff, and increases in permeability would produce less runoff but more infiltration. Second, impacts to runoff were then evaluated by comparing the altered area to the total land area available at the actual or representative site that was contributing runoff to surface water. This method was used because of the direct relationship between impermeable area and runoff (Tomasko 1997b). On the basis of this procedure, large sites would be preferable to small ones because more land would be available at the larger site to mitigate the presence of the proposed construction and operation.

Potential impacts to floodplains during construction and normal operations were evaluated for two aspects: addition or subtraction (withdrawal) of water from a nearby river. In either case, the impacts were assessed by comparing the volume of water either added or withdrawn to average flow conditions in the actual or representative river. This method was implemented because of the direct relationship between volumetric flow and channel depth (Tomasko 1997b) and floodplain prediction. As with runoff, a site located near a large river would have smaller impacts than a site located near a small river or stream because the larger river would have a larger flow volume that could mitigate withdrawals or discharges easier than would a small stream.

Groundwater physical parameters could be impacted during construction by direct extraction from a well or a series of wells. Groundwater levels would decrease during pumping, and the direction of groundwater flow in the vicinity of the well would be changed. Similarly, groundwater extraction for normal operations could also impact the physical parameters. Potential impacts were evaluated by comparing the pumping rate with the current groundwater usage at the actual or representative sites and by using a simple drawdown model (Tomasko 1997b). This method was used because of the direct correlation between pumping rates and water table elevations.

Surface water quality was estimated by using simple mixing models to estimate contaminant concentrations based on the quantity and solubility of the constituents in the effluent stream and the average flow conditions in the actual or representative receiving water bodies (Tomasko 1997b). For groundwater quality, the maximum concentration at the water table (point of compliance) was estimated by using the one-dimensional analytical solution discussed in Section C.2.1.

Two generic environmental settings were evaluated for the disposal and manufacture and use options, a dry environment and a wet environment. For the dry environmental setting, the depth to groundwater was assumed to be large (100 to 500 ft [30 to 150 m]), consistent with the depth to groundwater at such locations as the mixed waste landfill at Sandia National Laboratories [Johnson et al. 1994]). For the wet setting, the depth to groundwater was assumed to be small (30 ft [9 m]). Because site-specific parameters are needed to quantify impacts, the PEIS provided only a qualitative discussion of impacts for activities assumed to occur in generic environmental settings (i.e., discussion of non-site-specific parameters such as water use, effluent volumes, paved areas, and excavation volumes).

C.2.3 Data Requirements

Input data for the analyses performed for the PEIS were obtained from various site and contractor reports, when possible. Engineering judgment and professional experience were used to define input parameters if site-specific data were not available or calculations were for a representative or generic setting.

C.3 BIOTIC RESOURCES

Impacts to ecological resources were evaluated for continued cylinder storage, and for the cylinder preparation, conversion, storage, manufacture and use, and disposal options. Potential impacts were evaluated for terrestrial and aquatic biota, including vegetation and wildlife, wetlands, and federal- and state-listed threatened and endangered species. The impact analysis focused on the radiological and chemical toxicity effects to biota resulting from exposure to depleted UF_6 and related compounds and from physical disturbance to biota and habitats.

C.3.1 Continued Cylinder Storage and Cylinder Preparation

The impact analysis for continued cylinder storage and cylinder preparation included site-specific evaluation of impacts to biota in the vicinity of the Portsmouth, Paducah, and K-25 sites. Exposure to the contaminants of concern (depleted UF_6, UO_2F_2, and HF) under current management practices was analyzed in the context of storage cylinder integrity and potential release of contents, including effects of groundwater contamination, surface water contamination, contamination of soils, and airborne transport of contaminants. Also assessed were other effects of the operation of the three facilities associated with continued storage of depleted UF_6 that might impact biota (e.g., air quality) and potential impacts from cylinder preparation with respect to habitat loss and changes in biotic communities.

C.3.2 Other Options

The other options for management of depleted UF_6 were evaluated in generic terms, based on the following potential components: technologies for converting depleted UF_6 to other forms or products (including potential exposure to those forms or products and residual products and waste); technologies for using depleted UF_6, long-term storage of depleted UF_6 or uranium oxides; and disposal of depleted UF_6 or uranium oxides (including potential exposure to those compounds). The analysis considered potential impacts of these options to biota in the vicinity of the three representative sites (i.e., Paducah, Portsmouth, and K-25 sites) for all options but disposal and manufacture and use, for which generic environmental settings were assumed.

C.3.3 Impact Analysis

The analysis of impacts to wildlife addressed the effects of facility construction and operations — such as air quality, radiological, and chemical toxicity effects — through the exposure pathways of inhalation, dermal contact, and ingestion. Exposures were based on predicted air, surface water, groundwater, and soil concentrations of contaminants. Predictive modeling is discussed in Sections C.1 and C.2 of this appendix. Radiological dose rate estimates (in rad/day) were calculated for aquatic biota (fish and shellfish) on the basis of undiluted effluent concentrations (in pCi/L), energy released per decay (MeV) for depleted uranium, and a bioconcentration factor (factors of 2 and 60 were applied for fish and shellfish, respectively). These dose rate estimates were compared with the dose limit of 1 rad/d specified in DOE Order 5400.5. Additionally, concentrations of uranium, uranium compounds, and HF in air, water, and/or soil were compared with published benchmark values (levels with no, or lowest observed, effects) for determination of potential toxicity effects. Benchmark values for air concentration lowest observable effects due to inhalation were 7 mg/m^3 for HF, 17 mg/m^3 for triuranium octaoxide (uranyl uranate, U_3O_8), 1 mg/m^3 for uranium dioxide (UO_2), and 0.5 mg/m^3 for UF_4 (Voegtlin and Hodge 1949). The benchmark value for aquatic toxicity was a lowest observable effect level of 150 μg/L for total uranium (Hyne et al. 1992). Potential impacts analyzed included impacts to individuals (such as mortality, physical disturbance, injury, or reduction of reproductive capacity) and potential changes in biotic community structure or function (such as changes in species dominance, trophic relationships, or ecological processes).

The analysis of ecological impacts to plant species addressed facility construction and operations effects (such as removal of vegetation during construction) and chemical toxicity effects. Estimated uranium soil concentrations were compared with a benchmark value of 5 μg/g, which is the lowest observed effects concentration (Will and Suter 1994). Potential impacts analyzed included impacts to individuals (such as mortality, reduction of productivity) and potential changes in biotic community structure or function (such as changes in species dominance, species diversity, or ecological processes).

Physical disturbances to biota and habitats were also evaluated. The general guidelines used to assess impacts of habitat loss and wildlife disturbance were as follows: (1) negligible impacts, corresponding to less than 10 acres of required land; (2) moderate impacts, corresponding to between 10 and 100 acres of required land; and (3) potential large impacts, corresponding to greater than 100 acres of required land. The potential for impacts to wetlands and federal- and state-listed threatened or endangered species is a site-specific consideration, and it would be determined in Phase II analyses and *National Environmental Policy Act* (NEPA) reviews.

C.3.4 Data Requirements

Data input for the impact analysis included plant and animal species known to occur or potentially occurring at each storage site and in ecosystems (such as wetland, forest, grassland) in the vicinity of each site. Also required was information regarding potential releases due to cylinder failure, transportation, processing of depleted UF_6 and related compounds, handling (such as during repackaging), and disposal. Chemical and physical properties of depleted UF_6 and related compounds were required, including fate in soil, air, and water (such as adsorption or transformation).

C.4 ENVIRONMENTAL RADIATION SOURCES AND EXPOSURES

C.4.1 Normal Operations

Radiological impacts to human health from normal operations at different facilities were assessed for the continued storage option and for different categories of options. The option categories corresponded to the different technologies developed in the engineering analysis report (LLNL 1997). Additional details on the analysis of radiological impacts under normal operations are presented in Cheng et al. (1997).

C.4.1.1 Receptors

For the PEIS, radiation effects during normal (or routine) operations were estimated by first calculating the radiation dose to workers and members of the general public from the anticipated activities required under each alternative. The analysis considered three groups of people: (1) involved workers, (2) noninvolved workers, and (3) members of the general public, defined as follows:

- ***Involved Workers*** — Persons working at a site who are directly involved with the handling of radioactive or hazardous materials:
  - Might be exposed to direct gamma radiation emitted from radioactive materials, such as depleted UF_6 or other uranium compounds.
  - Would receive very small radiation doses from inhaling uranium compared with the direct radiation doses resulting from enclosed processes; ventilation controls would be used to inhibit airborne emissions in facilities.

  - Would be protected by a dosimetry program to control doses below the maximum regulatory limit of 5 rem/yr for workers (10 *Code of Federal Regulations* [CFR] Part 835).

- ***Noninvolved Workers*** — Persons working at a site but not directly involved with the handling of radioactive or hazardous materials:

  - Might be exposed to direct radiation from radioactive materials (although at a great distance) and to trace amounts of uranium released to the environment through site exhaust stacks.

  - Would receive radiation exposure primarily through inhalation of radioactive material in the air, external radiation from radioactive material deposited on the ground, and incidental ingestion of soil.

- ***Members of the General Public*** — Persons living within 50 miles (80 km) of the site:

  - Might be exposed to trace amounts of uranium released to the environment through exhaust stacks or wastewater discharges.

  - Would receive radiation exposures primarily through inhalation of radioactive material in the air, external radiation from deposited radioactive material, and ingestion of contaminated water, food, or soil.

For each of these groups, doses were estimated for the group as a whole (population or collective dose), as well as for a maximally exposed individual (MEI). The MEI was defined as a hypothetical person who — because of proximity, activities, or living habits — could receive the highest possible dose. The MEI for noninvolved workers and members of the general public usually was assumed to be at the location of the highest on-site or off-site air concentrations of contaminants, respectively — even if no individual actually worked or lived there. The average individual dose for involved workers was estimated, rather than the MEI dose, because of uncertainties about involved worker activities and locations. Under actual conditions, all radiation exposures and releases of radioactive material to the environment are required to be as low as reasonably achievable (ALARA), a practice that has as its objective the attainment of dose levels as far below applicable limits as possible.

C.4.1.2 Radiation Doses and Health Effects

All radiological impacts were assessed in terms of committed dose and associated health effects. The calculated dose was the total effective dose equivalent (10 CFR Part 20), which is the sum of the effective dose equivalent from exposure to external radiation and the 50-year committed effective dose equivalent from exposures to internal radiation. Radiation doses were calculated in units of milliroentgen-equivalent man (mrem) for individuals and in units of person-rem for collective populations.

The potential radiation doses resulting from normal operations would be so low that the primary adverse health effects would be the potential induction of latent cancer fatalities (LCFs). Health risk conversion factors (expected LCFs per absorbed dose) from Publication 60 of the International Commission on Radiological Protection (ICRP 1991) were used to convert radiation doses to LCFs, i.e., 0.0005 per person-rem for members of the general public and 0.0004 per person-rem for workers. Adverse health effects for individuals were assessed in terms of the probability of developing an excess LCF, whereas adverse health effects for collective populations were assessed as the number of excess LCFs expected in the population.

C.4.1.3 Exposure Pathways

External radiation would be the primary exposure pathway for involved workers due to the direct handling of radioactive materials and/or the close working distances to radiation sources. Radiation exposures through inhalation and incidental ingestion of contaminated particulates would be possible but would be expected to be very small compared with exposures from external radiation. Operations that could result in potential airborne emissions would be conducted under a fume hood or in glove boxes. Even if airborne emissions did occur, the use of high-efficiency particulate air (HEPA) filters and various air circulation systems would reduce the airborne pollutants in the working place to a minimal level. Exposures from inhalation could also be prevented by implementation, as required, of as low as reasonably achievable (ALARA) practices, such as workers wearing respirators while performing activities with potential airborne emissions. Potential exposure from incidental ingestion of particulates could be reduced by workers wearing gloves and exercising good working practices. On the basis of the small stack emission rates of radioactive materials estimated in the engineering analysis report (LLNL 1997) and the implementation of various mitigative measures, radiological impacts to involved workers were analyzed only for external radiation exposures.

Inhalation of contaminated particulates and incidental ingestion of deposited particulates were considered for noninvolved workers who, because of being located farther away from the radiation sources handled in the facilities, would not be exposed to direct external radiation from those sources. However, secondary external radiation would be possible from the deposited radionuclides on ground surfaces and from airborne radionuclides when the emission plume from the stacks of the processing buildings passed the locations of the noninvolved workers. To obtain conservative estimates with the calculation, the noninvolved workers were assumed to be exposed to radiation caused by airborne emissions without any shielding from buildings or other structures.

Radiation exposures of members of the off-site general public were assessed for both airborne and waterborne pathways. The airborne pathways included inhalation of contaminated particulates, external radiation from deposited radionuclides and from airborne radionuclides, incidental ingestion of deposited radionuclides, and ingestion of contaminated food products (plants, meat, and dairy products). Plants grown in the area where the emission plume passed could become contaminated by deposition of radionuclides on the leaves or ground surfaces. Radionuclides deposited on leaves could subsequently translocate to the edible portions of the plants, and those deposited on ground surfaces could subsequently be absorbed by plant roots. Livestock and their products could become contaminated if the livestock ate the contaminated surface soil and plants.

The waterborne pathways included ingestion of surface water and groundwater; ingestion of contaminated plant foods, meat, and dairy products; and potential radon exposure from using contaminated water. Plant foods and fodder could be contaminated from irrigation with contaminated water, and the livestock and their products could become contaminated if the livestock were fed with contaminated water and ate contaminated fodder. Potential indoor radon exposures would be possible if contaminated water was used indoors and radon gas emanated from the water. Because of the large dilution capability of surface water at the representative sites, the estimated radionuclide concentrations in surface water were always very low, and potential radiation exposures from the food chain pathways associated with these low water concentrations would be negligible. Therefore, radiation exposures resulting from contaminated surface water were assessed only for the drinking water pathway. The dilution capability would be smaller for groundwater, resulting in higher groundwater concentrations. Therefore, if the groundwater would be contaminated, radiation exposures from the food chain pathways, radon pathway, and drinking water pathway were all estimated.

C.4.1.4 Sources of Data and Application of Software

The external exposures incurred by the involved workers were estimated on the basis of information on worker activities, radiation sources, and exposure distances provided in the radiation exposure and manpower distribution estimating data in the engineering analysis report (LLNL 1997), with the use of the MicroShield (Negin and Worku 1992) computer code. MicroShield is a commercial software program designed to estimate external radiation doses from a variety of sources; it is widely used for such applications. It was used to calculate the external radiation dose rate associated with each worker activity, which was then used to calculate collective worker exposures. After collective worker exposures were determined, the average worker dose was calculated by dividing the collective dose by the number of involved workers. At this preliminary stage of engineering design, the information on radiation sources, worker activities, and number of required workers is subject to a large degree of uncertainty, as are the calculated collective and average worker doses. Therefore, the calculation results presented should be used only for comparative purposes among different technologies and options. In reality, the radiation dose to the individual worker would be monitored and maintained below the DOE administrative control limit of 2,000 mrem/yr (DOE 1992b), which is below the regulatory dose limit of 5,000 mrem/yr (10 CFR Part 835).

Radiological impacts from airborne pathways were estimated with the emission data provided in the engineering analysis report (LLNL 1997), with the use of the GENII (Napier et al. 1988) computer code, which was also used in several previous environmental impact statement projects, such as the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (WM PEIS; DOE 1997), for the same application. The GENII computer code uses the site-specific or representative meteorological data (joint frequency data) selected for each option to estimate the air concentrations at downwind locations. It then calculates the biota concentrations by using biotransfer models and estimates the radiation doses with a built-in dosimetry model.

The MEI for the noninvolved workers was assumed to be within the site boundary at a location that would have the maximum air concentration and would yield the largest radiation dose. For the general public, the location of the MEI was assumed to be either at the site boundary or at an off-site location that would have the largest air concentration. The site boundary was determined with actual site information (for the three current storage sites) or with the information on facility dimensions provided in the engineering analysis report (LLNL 1997). If the facility was assumed to be at one of the three representative sites, the collective dose for the noninvolved workers was estimated with information on sitewide worker distribution. If no exact location was determined for the facility, the noninvolved workers in the facility were assumed to be evenly distributed between 100 to 200 m from the emission point. Population distributions within 50 miles (80 km) around the three representative sites were obtained from census data and were used to estimate the collective dose to the off-site public. For facilities without specific locations, a representative population density of 6 persons/km^2 was used for a rural environment and 275 persons/km^2 was used for an urban environment. These would result in a total population of approximately 120,000 and 5,600,000 within a radius of 50 miles (80 km) for a rural and urban environment, respectively.

Surface water and groundwater concentrations were obtained through water quality analyses. Biota concentrations (plant foods, meat, and milk) and indoor radon concentrations from using contaminated groundwater were estimated with the RESRAD code (Yu et al. 1993). The RESRAD code contains biotransfer models comparable with those in GENII to estimate biota concentrations but also has the capability to predict indoor radon concentrations and the associated radiation doses.

C.4.1.5 Exposure Parameters and Dose Conversion Factors

Inhalation rates for workers were assumed to be 1.2 m^3/h (ICRP 1994), with an exposure duration of 8 hours per day for 250 days per year. Incidental ingestion of particulates was assumed to be 50 mg/d for the workers. The inhalation rate for the general public was assumed to be 20 m^3/d, with an exposure duration of 24 hours per day for 365 days per year. The ingestion rates for drinking water and soil for the general public were assumed to be 2 L/d for water, 100 mg/d of soil for adults, and 200 mg/d of soil for children. No building shielding effect was considered for inhalation and external radiation exposures. Therefore, radiation doses estimated in this way would be greater than the actual doses, which would always be associated with some shielding from buildings.

Site-specific agriculture data (yield per unit area) for food crops and fodder were used for the three cylinder storage sites (Oak Ridge National Laboratory 1995). When the location of the facility was not specified, the default agriculture data in the GENII and RESRAD computer codes were used. Default food consumption data from the two codes were also used, which were close to each other and would both result in conservative estimates of the ingestion doses. Nevertheless, in all the options examined, radiation doses from the food ingestion pathways constituted just a small fraction of the total dose, which is dominated (>95%) by doses from inhalation (for airborne pathways) or ingestion of drinking water (for waterborne pathways).

The GENII computer code incorporates an internal dosimetry model to estimate the committed effective doses from internal radiation, whereas the RESRAD code uses the EPA internal dose conversion factors (EPA 1988) to estimate internal doses. Previous benchmarking studies (Faillace et al. 1994) showed that the two methods resulted in approximately the same radiation doses under the same exposure conditions. The inhalation doses depend strongly on the solubilities of the inhaled chemicals. With high solubility, a chemical would be excreted from the human body within a shorter period of time and would result in less internal exposure. Except for UO_2F_2 and UF_4, which were assumed to be excreted from the human body within a few days and a few weeks, respectively (due to the high and moderate solubilities in water), all other uranium chemicals considered in this PEIS were assumed to remain in the human body for years, thus resulting in greater radiation exposures. The ingestion doses were estimated by assuming that the uranium compounds would be absorbed by the gastrointestinal tract to the largest extent possible for uranium compounds; this would result in the maximum internal exposure.

C.4.2 Accident Conditions

For the assessment of radiological impacts under accident conditions, an accident was defined as a series of unexpected or undesirable events leading to a release of radioactive or hazardous material within a facility or the general environment. Accident source terms were defined as the amounts of radioactive or hazardous materials released to the atmosphere from the primary container or confinement in dispersible forms. Accident scenarios, source terms, and frequencies for most component activities of the alternative management strategies are provided in the engineering analysis report (LLNL 1997). For continued cylinder storage at the current sites and long-term storage as UF_6 in yards, the accident information was obtained from the safety analysis reports for the three storage yards (Lockheed Martin Energy Systems, Inc. [LMES] 1997 a-c). The health impacts from depleted uranium compounds would be expected to be dominated by their chemical toxicity and not by their radiological effects. A lethal exposure from the chemical toxicity of uranium would occur with an internal radiation dose of about 1 rem, which is a dose not considered to have any significant radiation health effects.

C.4.2.1 Receptors

Radiation doses and health risk effects were calculated for noninvolved workers and the general public. Population doses were calculated up to a distance of 50 miles (80 km) from the release point. Except under the continued cylinder storage and cylinder preparation options, where actual locations of storage yards were used, all accidental releases were assumed to be at the centers of the representative or generic sites. Ten downwind distances and 16 wind directions were applied. Radiation doses were calculated for the following receptors for accident conditions:

- ***Noninvolved MEI Worker:*** A worker located on-site at the point of maximum air concentration for uranium compounds (but more than 330 ft [100 m] from the accident location).
- ***Noninvolved Worker Population:*** All workers on the site located more than 330 ft (100 m) from the accident location (including those workers in the facility where the accident occurred).
- ***Off-Site MEI:*** A hypothetical member of the general public living off-site and receiving the maximum exposure from accidental releases.
- ***General Population:*** General population within a 50-mile (80-km) radius of the site where the accident might occur.

During an accident, involved workers might be subject to severe physical and thermal (fire) forces and could be exposed to releases of chemicals and radiation. The risk to the involved workers is very sensitive to the specific circumstances of each accident and 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 and thermal forces causing or caused by the accident, meteorological conditions, and characteristics of the room or building if the accident occurred indoors. However, it is recognized that worker injuries and fatalities are possible from chemical, radiological, and physical forces if an accident did occur.

C.4.2.2 Radiological Doses and Health Risks

Radiological consequences were calculated in terms of total effective dose equivalent (TEDE) and LCF. The TEDE is the sum of the effective dose equivalent from external radiation and the 50-year committed effective dose equivalent from internal radiation. Radiation doses were expressed in units of rem for individuals and in units of person-rem for populations. The health risk conversion factors provided in ICRP Publication 60 (ICRP 1991) were used to calculate LCFs. These factors are 0.0004/rem for workers and 0.0005/rem for members of the general public. The conversion factor for the public is slightly higher than that for workers because some individuals in the public, such as infants, are more sensitive to radiation than the average worker. If these conversion factors are applied to the individual dose, the result is the individual increased lifetime probability of developing an LCF. If these factors are applied to collective (population) dose, the result is the number of excess LCFs.

C.4.2.3 Methodology

Radiation doses from atmospheric releases were evaluated by using the GENII computer code (Napier et al. 1988) developed at Pacific Northwest Laboratory. The code implements the internal dosimetry models recommended by the ICRP in Publication 26 (ICRP 1977) and Publication 30 (ICRP 1979). The GENII code considers the transport of radioactive material in air, soil, water, and food sources to the human body. To achieve consistency in the impact analysis among chemical and radiological releases, air concentrations per unit release were derived by using the HGSYSTEM (Post 1994a-b; Hanna et al. 1994) and FIREPLUME (Brown et al. 1997) models and used as input to GENII. The GENII code was used to develop baseline radiation doses from unit releases (release-to-dose conversion factors) to the various receptors. Accident consequences were then calculated by multiplying the dose conversion factors with the actual source terms for each accident.

Accident frequencies are categorized into four groups:

- I — Likely (L): Accidents estimated to occur one or more times in 100 years of facility operations (frequency $\geq 1 \times 10^{-2}$/yr).

- II — Unlikely (U): Accidents estimated to occur between once in 100 years and once in 10,000 years of facility operations (frequency = from 1×10^{-2}/yr to 1×10^{-4}/yr).

- III — Extremely Unlikely (EU): Accidents estimated to occur between once in 10,000 years and once in 1 million years of facility operations (frequency = from 1×10^{-4}/yr to 1×10^{-6}/yr).

- IV — Incredible (I): Accidents estimated to occur less than one time in 1 million years of facility operations (frequency $< 1 \times 10^{-6}$/yr).

The results of the accident impacts were summarized on the basis of these frequency categories. One accident was selected in each category. The chosen accident was the one that would result in the highest dose to the general public MEI; that accident was then the bounding accident (most conservative) in that frequency category. The probability of occurrence for an accident is indicated by its frequency category. For example, an accident that belongs to the extremely unlikely category has a probability of occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. Therefore, the overall risk of an LCF to the receptors can be estimated by multiplying the LCF result by the probability of occurrence of the accident and by the number of years of operations.

C.4.2.4 Exposure Pathways

Atmospheric releases from accidents would result in radiation exposure to various receptors through the following pathways: (1) external exposure from immersion in the plume containing the airborne radioactive material (air submersion), a pathway considered in the dose calculations for all receptors; (2) external exposure from radioactive material deposited on the ground (ground irradiation or groundshine), a pathway included in the dose calculations for the off-site MEI and general population; (3) internal exposure from inhalation of radioactive airborne material in the plume (inhalation), a pathway considered in the dose calculations for all receptors; (4) internal exposure from inhalation of radioactive airborne material suspended in air due to wind action (inhalation), a pathway included in the dose calculations for the off-site MEI and general population; and (5) internal exposure from the ingestion of food crops and animal products (ingestion), a pathway included in the dose calculations for the off-site MEI and general population. The plume inhalation pathway was found to dominate other pathways, accounting for more than 99% of the dose.

C.4.2.5 Data Requirements

A variety of data were used in GENII for dose calculations. Unless different values were provided, the values used in the PEIS are listed in Table C.1.

C.5 CHEMICAL SOURCES AND EXPOSURES

The approach taken for addressing nonradiological human health and safety impacts is outlined below. The assessment included risk during normal facility operations, risk from accidental chemical releases, and risk of physical injury (industrial risk).

C.5.1 Normal Operations

This section describes the methodologies used for assessing chemical impacts on human health from normal operations of different facilities. Chemical impacts were assessed for different categories of options, which correspond to the different technologies developed in the engineering analysis report (LLNL 1997), as well as to continued cylinder storage.

C.5.1.1 Receptors

The assessment of health risks associated with chemical sources and exposures was consistent with the assessment of radiological risks, insofar as possible. The receptors evaluated included MEIs for noninvolved workers (i.e., those not involved in handling hazardous chemicals) and the general public. Because the standard methodologies for chemical health risk assessment do

TABLE C.1 Parameters and Values Used for Dose Calculations with the GENII Code

Parameter	Values Used in GENII Code
Inhalation	Chronic breathing rate = 1.2 m^3/h Acute breathing rate = 1.5 m^3/h Plume exposure time = 100% of plume duration Internal exposure period for dose calculation = 50 years
Air submersion	Immersion duration = 100% of plume duration
Ground irradiation	Exposure to contaminated soil = 1 year Building shielding factor = 0.3, which represents exposure of an individual to contaminated soil 8 hours per day or 2,920 hours per year
Ingestion	Ingestion takes place over a period of 1 year Internal exposure period for dose calculation = 50 years Ingestion of contaminated food = 100% of total consumption rates for the MEI and 10% of total consumption rates (30% for milk) for the general population Annual dietary consumption rates (kg/yr): Leafy vegetables = 18.3; Beef = 84.7 Root vegetables = 73.4; Poultry = 9.5 Fruits = 68.3; Milk = 111.7 Grain = 35.4; Egg = 15.0
Meteorology	For 95% meteorological conditions, Pasquill Class F, with a wind speed of 1 m/s in all directions For 50% meteorological conditions, Pasquill Class D, with a wind speed of 4 m/s in all directions
Other default data	Plume mixing layer height = 1,000 m Infinite plume and far-field release conditions Wet deposition = 0 Deposition velocity = 0.001 m/s for particulates, 0.01 m/s for iodines, and 0 for noble gases Soil density = 1.5 g/cm^3 Depth of surface soil available for resuspension = 10 cm Soil resuspension calculated in the code using the Anspaugh model Leaf resuspension factor = 1.0×10^{-9}/m
Site-specific data	Population distribution at each site Location of MEI at each site Meteorological data at each site Description of accident scenarios Release elevation (m) (ground release vs. stack release) for each accident Frequency of each accident

not usually involve assessment of collective (population) dose or risk, population risk was not generally evaluated for chemical exposures. However, if a health risk was shown to exist for the MEI in any of the receptor groups assessed, additional assessment of the likely number of individuals affected was evaluated.

Because of the conceptual nature of the facility designs, individual worker activities were highly uncertain, and process-specific chemical concentrations could not be accurately estimated. As a result, potential impacts to the involved worker MEI were not quantified for normal operations at the different facilities. However, potential exposures of involved workers to chemicals generated during the various processes would be addressed by proposed U.S. Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) for soluble uranium compounds and for HF (29 CFR Part 1910, Subpart Z, as of March 1998). To maintain compliance with OSHA standards, it is likely that chemical exposures would be minimized by various engineering mitigative controls (e.g., fume hoods and glove boxes and heating, ventilating, and air conditioning [HVAC] designs for high hazard areas) and extensive indoor air monitoring.

C.5.1.2 Chemical Doses and Associated Health Effects

For normal operations, risks were expressed by using the hazard quotient concept for exposures to noncarcinogens (i.e., comparison of estimated receptor doses with reference levels or doses below which adverse effects would be very unlikely to occur). In general, the chemicals of concern for this PEIS were uranium and fluoride compounds, especially HF gas. These substances would not be chemical carcinogens, so cancer risk calculations were not applicable. The toxicity of the exposures for relevant receptors was estimated through comparison with oral and inhalation reference levels (levels below which adverse effects would be very unlikely to occur). The oral reference dose of 0.003 mg/kg-d was used for evaluating risks from ingestion of soluble uranium compounds; EPA derived this value based on a lowest-observed-adverse-effect level in rabbits of 3 mg/kg-d of uranyl nitrate hexahydrate combined with an uncertainty factor of 1,000 (Maynard and Hodge 1949; EPA 1998a). Because of conflicting results concerning absorption of insoluble uranium compounds such as U_3O_8 and UO_2 from the gastrointestinal tract, the oral reference dose of 0.003 mg/kg-d was also used in this analysis for calculating hazard quotients for these compounds. This assumption is conservative because the gastrointestinal tract would absorb a smaller amount of insoluble than soluble uranium compounds.

Inhalation reference concentrations for uranium compounds and hydrogen fluoride are not currently available from standard EPA sources. To assess potential risks from inhalation of these compounds, interim reference levels were developed from proposed OSHA PELs (29 CFR Part 1910, Subpart Z, as of March 1998). The 8-hour time-weighted-average PEL for soluble and insoluble uranium compounds is 0.05 mg/m^3; for HF it is 2.5 mg/m^3. These values were converted to assumed inhalation reference level values for noninvolved workers in mg/kg-d by assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg, resulting in interim worker inhalation reference level values of 0.014 and 0.71 mg/kg-d for uranium compounds and hydrogen fluoride, respectively. To generate interim inhalation reference levels values for the general public, these worker values were adjusted to account for increased exposure duration of the general public (assumed 168 hours per week instead of 40 hours per week); an additional uncertainty factor of 10 was used to account for sensitive subpopulations in the general public. This results in interim inhalation reference levels for the general public of 0.0003 and 0.02 mg/kg-d for uranium compounds and hydrogen fluoride, respectively.

The reference levels used for preliminary evaluation of general public hazard quotients and carcinogenic risks from the existing environment at the three current storage sites (see Sections 3.1.7.2, 3.2.7.2 and 3.3.7.2) were obtained from the EPA's Integrated Risk Information System (IRIS) when available (EPA 1998a). The slope factor value used for trichloroethylene was obtained from the EPA's National Center for Environmental Assessment (Choudhury 1996). The derived reference concentration levels for uranium compounds and HF discussed above were used as reference levels for evaluating inhalation of these substances.

C.5.1.3 Exposure Pathways and Parameters

For the noninvolved worker MEI, chemical intakes and health risks from inhalation of uranium compounds and HF were assessed, provided that there were airborne emissions from the facility being evaluated. Incidental ingestion of uranium compounds deposited on soil was also assessed. For the general population MEI, intake of uranium compounds and HF was summed over all appropriate potential air-associated pathways (i.e., inhalation and incidental ingestion of contaminants deposited on soil). Soil-related pathways other than incidental ingestion would have been evaluated only if the predicted soil concentrations were high enough to indicate that intakes via the food chain would be significant. Data for uranium compounds generated for the radiological impact analyses by the GENII computer code were used to derive appropriate uranium concentration levels for the various environmental media. Air dispersion modeling for HF, as discussed in Section C.1, was used to obtain the air concentration of HF at the MEI location. Additional exposures for the MEI would include ingestion of contaminated water, for which uranium concentrations were provided through modeling of contaminant transport from effluent sources into surface waters and/or groundwater. Pathways involving the ingestion of plant foods, meat, and dairy products contaminated through the use of groundwater for irrigation were included when failure of engineering barriers and containers could result in the eventual leaching of uranium to groundwater.

Appropriate exposure factors for the various pathways evaluated can generally be obtained from EPA guidance documents. Generally, the worker MEI was assumed to be exposed for 8 hours per day, 250 days per year, for a period of 25 years. The MEI for the general public was assumed to be exposed for 24 hours per day, 365 days per year, for a period of 30 years. These exposure factors were modified as appropriate for various options and predicted exposure circumstances.

C.5.1.4 Exposure Modeling and Risk Evaluation

Media-specific concentrations of contaminants associated with the normal operation of facilities for the various options were modeled on the basis of effluent data provided in the engineering analysis report (LLNL 1997). For airborne pathways, these effluent amounts were modeled by using either the GENII computer code (see Section C.4.1.4) or the ISCST computer code (see Section C.1). Surface water and groundwater concentrations were obtained through water quality analyses (see Section C.2).

Modeled concentrations of contaminants in the various environmental media were used to estimate average daily intakes for the various receptors examined. The ratios of the daily intakes to appropriate reference dose levels were calculated to generate hazard quotients. Hazard quotients were summed for individual contaminants and across all appropriate exposure routes (e.g., inhalation, soil ingestion) to generate hazard indices for the noninvolved worker and general public MEIs for the various options. These hazard indices were compared with the reference hazard index of 1. A hazard index of less than 1 is interpreted to indicate that adverse noncancer effects are very unlikely; a hazard index of greater than 1 would indicate that adverse effects are possible for the MEI, and that further investigation of potential exposures and additivity of individual contaminant toxicity would be warranted.

When no adverse effects would be expected for the MEI of a given population (i.e., the hazard index is less than 1), then by definition no adverse effects would be expected in that population. Therefore, calculation of population risks is not applicable when MEI hazard indexes are less than 1.

C.5.2 Accident Conditions

C.5.2.1 Health Criteria

For the assessment of the impact of source terms from accidental releases in this PEIS, two primary potential health effects endpoints were evaluated: adverse effects and irreversible adverse effects. Evaluation of these two health endpoints was consistent with the accident evaluations typically conducted to assess industrial risks (American Industrial Hygiene Association [AIHA] 1996) | and with the approach taken in the safety analysis reports (LMES 1997a-c) for the three sites. The selection of appropriate health criteria (e.g., intake levels or air concentrations) to represent these health effect endpoints for uranium compounds and for other chemicals of potential concern is discussed in the following subsections. It should be noted that human responses do not occur at precise exposure levels but can extend over a wide range of concentrations. The values used as guidelines for potential adverse effects and potential irreversible adverse effects in this PEIS should not be expected to protect everyone but should be applicable to most individuals in the general population. In all populations, there are hypersensitive individuals who will show adverse responses at exposure concentrations far below levels at which most individuals would normally respond (AIHA 1996). Alternatively, some individuals will show no adverse response even at exposure concentrations somewhat higher than the guideline levels.

On the basis of health criteria levels discussed below, the models described in Section C.5.2.2 were used to generate contours for the appropriate air concentration levels. The number of workers or the number of people from the general population projected to be inside each contour were the number of individuals tabulated as at risk for the health effect endpoint (e.g., potential irreversible adverse effects).

In addition to potential adverse effects and irreversible adverse effects, the number of fatalities from accidental chemical exposures was estimated to facilitate comparisons with radiological impacts. For exposures to uranium and HF, it was estimated that the number of fatalities occurring would be about 1% of the number of irreversible adverse effects (EPA 1993a; Policastro et al. 1997). Similarly, for exposure to ammonia, the number of fatalities was estimated to be about 2% of the number of irreversible adverse effects (Policastro et al. 1997).

C.5.2.1.1 Potential Irreversible Adverse Effects

Uranium. An intake of 30 mg of uranium was used as the health criterion for potential irreversible adverse effects for exposure to all forms of uranium evaluated in the PEIS. The background document for the U.S. Nuclear Regulatory Commission (NRC) regulations for the Certification of Gaseous Diffusion Plants (10 CFR 76) states that "in assessing the adequacy of protection of the public health and safety from potential accidents, the NRC will consider whether the potential consequences of a reasonable spectrum of postulated accident scenarios exceed 0.25 Sv (25 rem), or uranium intakes of 30 mg, taking into account the uncertainties associated with modeling and estimating such consequences" (NRC 1994). According to these regulations, the selection of the 30 mg uranium intake level as an evaluation guideline level for irreversible injury was based on information provided in Fisher et al. (1994). This intake level was also used as the evaluation guideline for the off-site public and for noninvolved workers in accident analysis for evaluation basis events (annual frequency between 0.01 and 10^{-6}) conducted for the safety analysis reports for the three sites (LMES 1997a-c).

In applying the 30 mg uranium intake to accident analysis for the many uranium compounds considered in this PEIS (i.e., UO_2F_2, UF_4, uranium metal, U_3O_8, and UO_2), the following parameters were accounted for: molecular weight, solubility, inhalation rate, and duration of predicted exposure. On the basis of an inhalation rate of 1.5 m^3/h as the ventilation rate during light exercise (ICRP 1994), and on appropriate adjustments to account for the percent uranium in each compound, air concentrations corresponding to an intake level of 30 mg were calculated for modeled exposure durations. For example, the air concentration of 26 mg/m^3 UO_2F_2 corresponding to a 30 mg uranium intake for a 60-minute exposure to UO_2F_2 would be calculated as follows:

$$\frac{30\text{ mg uranium} \times 308/238\text{ (molecular weight } UO_2F_2\text{/molecular weight uranium)}}{1.5\text{ m}^3\text{/h} \times \text{modeled exposure duration (h)}}$$

Additionally, for the insoluble uranium compounds, an uptake factor was incorporated into the calculated air concentrations, based on ICRP guidance that 0.2% absorption be assumed for inhalation of less soluble uranium compounds that have biological half-lives of years (i.e., U_3O_8 and UO_2), as compared with 5% absorption for soluble and slightly soluble compounds such as UO_2F_2 and UF_4 (ICRP 1979).

Other Chemicals. Potential irreversible adverse effects were also assessed for exposure to other chemicals of concern with respect to accidental releases; these chemicals were HF, hydrochloric acid, ammonia, sulfuric acid, and nitric acid. Several of these substances would be used and/or transported only in dilute forms that would not result in potential for irreversible adverse effects if accidentally released (i.e., hydrochloric acid, sulfuric acid, and nitric acid). For HF and ammonia, levels corresponding to irreversible adverse effects for exposures of 1-hour duration were set at corresponding Emergency Response Planning Guideline 2 (ERPG-2) levels. The ERPG levels are developed for a variety of chemicals by the AIHA; ERPG-2 levels are defined as "the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action" (AIHA 1996). The ERPG-2 values are 20 parts per million (ppm) for HF and 200 ppm for ammonia; these values were used in the PEIS as evaluation guideline levels for potential for irreversible adverse effects for modeled exposure durations of 60 minutes.

The guideline exposure level of 20 ppm used to estimate irreversible adverse effects from HF exposure is likely to result in overestimates. This is because no deaths have been known to occur as a result of acute exposures (i.e., 1 hour or less) of animals or humans at concentrations of less than 50 ppm (AIHA 1988), and generally, if death does not occur quickly after HF exposure, recovery is complete (McGuire 1991).

The chemicals evaluated exhibit irritant characteristics; the toxicity of these substances is generally not linearly proportional to the intake amount. For example, the toxic effect of exposure to 32 mg/m^3 HF for 30 minutes would actually be greater than the toxic effect of exposure to 16 mg/m^3 HF for 60 minutes, because the irritant action of the HF is greater at higher air concentrations. Data on the appropriate adjustments of HF concentrations for evaluation of shorter exposure times are presented and discussed in various documents dealing with the toxicity of uranium hexafluoride (Fisher et al. 1994; McGuire 1991). On the basis of these data, for modeled exposure durations of between 5 and 60 minutes, the air concentrations of HF and ammonia corresponding to the ERPG-2 value were calculated from:

$$C = C_{ERPG\text{-}2}(60/t)^{0.5}$$

where:

C = adjusted exposure guideline value and

t = modeled exposure duration (min).

It was conservatively assumed that the 5-minute adjusted exposure guideline value would be applied even for modeled exposure durations of less than 5 minutes.

C.5.2.1.2 Potential Adverse Effects

Uranium. An intake of 10 mg of uranium was used as the health criterion for potential adverse effects for exposure to all forms of uranium evaluated in the PEIS. This value was based on conclusions stated in NUREG-1391 (McGuire 1991) that "an intake level of soluble uranium with no significant detectable health effects, transient or permanent, appears to be about 10 mg in round numbers." This level was also used as the evaluation guideline for the off-site public and noninvolved workers for accident analysis of anticipated events (annual frequency between 0.1 and 0.01) conducted for the safety analysis reports for the three sites (LMES 1997a-c).

Adjustment of the 10-mg intake level for the various uranium compounds and modeled exposure durations was conducted in the same manner as for evaluation of irreversible adverse effects (see Section C.5.2.1.1).

Other Chemicals. Potential adverse effects were assessed for exposure to HF and ammonia by using ERPG-1 levels. ERPG-1 levels are defined as "the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing any but mild transient adverse health effects or perceiving a clearly defined objectionable odor" (AIHA 1996). The ERPG-1 value is 1.6 mg/m^3 for HF and 25 ppm for ammonia; these values were used in the PEIS as evaluation guideline levels for potential adverse effects for modeled exposure durations of 60 minutes. Scaling of these values for modeled exposure durations of less than 60 minutes was conducted in the same manner as for evaluation of irreversible adverse effects (see Section C.5.2.1.1). As for irreversible adverse effects, it was conservatively assumed that the 5-minute adjusted exposure guideline value would be applied even for modeled exposure durations of less than 5 minutes.

C.5.2.2 Methods and Models

Accident scenarios, source terms, and frequencies for most component activities of the alternative management strategies were provided in the engineering analysis report (LLNL 1997). For continued cylinder storage at the current sites and long-term storage as UF_6 in yards, this accident information was obtained from the safety analysis reports for the three storage yards (LMES 1997a-c). For options considered under each activity, the reference document(s) provided the hypothetical accident, as well as the release amount as a function of time and duration of release and any special characteristics of the accidents. Accidents may be due to natural phenomena (earthquakes, tornadoes, etc.) or due to process accidents or temporary storage facility accidents at the various facilities. The chemical accidents often include fires and involve such chemicals as depleted UF_6 (liquid or solid form), and its degradation products UO_2F_2 and HF, uranium oxides, or the metallic form of uranium. The chemicals identified for accident scenarios depend upon the specific options chosen (e.g., conversion, disposal).

Although all accident scenarios presented in the engineering analysis report for the various options were evaluated and consequences and impacts predicted, only those scenarios necessary to fully represent the range of potential consequences were quantitatively assessed in the PEIS. The following models were used to estimate downwind dispersion through air of releases of chemicals:

- HGSYSTEM (Post 1994a-b) for HF releases and releases of uranium compounds,
- HGSYSTEM/UF_6 model (Hanna et al. 1994) for UF_6 vapor releases, and
- FIREPLUME model (Brown et al. 1997) for releases from toxic fires of UF_6 and other chemicals.

Detailed descriptions of these models are provided in Policastro et al. (1997). Except for the tornado accident scenario, two meteorological conditions were assumed: D stability with 4 m/s wind speed and F stability with 1 m/s wind speed. Both sets of assumptions were evaluated, and the results are presented in this PEIS.

C.5.2.3 Receptors

For each accident, the impacts on noninvolved workers and the general population were estimated. No quantitative predictions of impacts were made for involved workers (see Section C.4.2.1).

Noninvolved workers were considered to be at risk for a given health endpoint if they were located within the plume contour (based on ERPG level or uranium intake level) for the wind direction that would lead to the largest worker count. Workers were assumed to be in the locations where they work and for conservatism, the protection provided by the building structure was not included. This computation involved the overlay of the plume contour from the source point and the rotation of the plume 30 to 100 times to identify the direction with the highest worker count. That count was reported in the impact evaluation.

Individuals in the general population were also considered to be at risk if they were located within the plume contour. For the wind direction that would lead to the largest general population count, a separate overlay was done for the predicted plume to determine maximum population affected for the human health endpoint for that accident. As usually was the case, the direction leading to the maximum worker count did not necessarily match the direction for the maximum general population count. The adverse effects and irreversible adverse effects contours were predicted for each accident, with the adverse effects contour the larger of the two. For UF_6 releases, both the UO_2F_2 contour and the HF contour were predicted for both adverse effects and irreversible adverse effects levels; in general, the HF contours were larger than the uranium contours and led to larger population risks.

The MEI worker was assumed to be located 100 m from the accident location. The MEI for the general population was assumed to be located at the nearest fence line position, although there are currently no residences at these locations at the three current storage sites. Impacts for MEIs are presented as "yes" or "no," depending upon whether the air concentrations of chemicals greater than or equal to corresponding adverse effects and irreversible adverse effects were modeled at the MEI locations.

C.5.2.4 Data Requirements

General data used in the accident predictions included the following:

- Estimate of the frequency of the accident per year,
- Release amounts (time history) and quantities for each chemical released,
- Number of workers on site and population off-site by direction, and
- Relative locations of source and receptors for both workers and members of the general public.

In the fire accident scenarios, the release quantities were presented as a function of time for the three phases of the release: puff, fire release, and cooldown. Fire and vapor temperatures were available as well for predictions.

C.5.3 Physical Hazards

The expected number of worker fatalities and injuries associated with each option was calculated based on statistics available from the Bureau of Labor Statistics, as reported by the National Safety Council (1995), and on estimates of total worker hours required for construction and operational activities for each option, as given in the engineering analysis report (LLNL 1997).

Construction and manufacturing annual fatality and injury rates were used for the construction and operational phases of each option. For injuries, rates for 1993 were used because 1994 rates were not yet available; for fatalities, estimated rates for 1994 were used. The use of data from two years should not result in incompatible data, since fatality rates in the applicable industry divisions were identical for 1993 and 1994. Injury incidence rates used were for injuries involving lost workdays (not including the day of injury).

The specific rates used in calculations for each option were as follows: fatalities during construction, 15 per 100,000 workers; fatalities during operations, 4 per 100,000 workers; injuries during construction, 5.5 per 100 full-time workers; injuries during operations, 5.3 per 100 full-time workers.

Fatality and injury risks were calculated as the product of the appropriate incidence rate (given above), the number of years for construction and operations, and the number of full-time equivalent employees for construction and operations for each option. The employment data reported in the engineering analysis report (LLNL 1997) were used to calculate option-specific risks. For construction, the data were generally reported in the engineering analysis report as peak and average employment for each year of construction (construction periods ranged from 4 to 20 years); the average number of employees for the peak construction year was used in risk calculations. For the operations phase, the fatality and injury rates were computed for all facility employees for each option (no distinction was made between involved and noninvolved workers). The available fatality and injury statistics by industry are not refined enough to warrant analysis of involved and noninvolved workers as separate classes.

The calculation of risks of fatality and injury from industrial accidents was based solely on historical industrywide statistics and therefore did not consider a threshold (i.e., any activity would result in some estimated risk of fatality and injury). Whatever alternative was implemented would be accompanied by best management practices, thereby reducing fatality and injury incidence rates.

C.6 SOCIOECONOMICS

C.6.1 Scope of the Analysis

Analysis of the socioeconomic impacts of the depleted UF_6 management options included assessment of the construction and operations impacts of continued storage, cylinder preparation, conversion, manufacture and use, long-term storage, and disposal. For continued storage and cylinder preparation, site-specific impacts were estimated by using the regions of influence (ROIs) surrounding the Paducah, Portsmouth, and K-25 sites. For conversion and long-term storage options (except long-term storage in mines), the ROIs surrounding the three current storage sites were also used as representative of locations where these types of facilities might be located in the future. For site-specific and representative site impacts, the analysis estimated the impacts of each option on (1) regional economic activity, including direct (on-site) and indirect (off-site) employment and income, (2) population in-migration, (3) local housing markets, and (4) local jurisdictional revenues and expenditures. The analyses for the manufacture and use, long-term storage in mines, and disposal options assumed generic, nonspecific sites for the required activities, although it was assumed that disposal would occur in a rural environment, whereas manufacture and use could occur in a range of population densities, from rural to urban. For the generic sites, the analysis was limited to estimating the impacts of each option on direct (on-site) employment and income. Additional details on the analysis of socioeconomic impacts is provided in Allison and Folga (1997).

Assessment of the socioeconomic impacts for transportation of depleted UF_6 was not included in the PEIS analysis. The transportation of depleted UF_6 would not be likely to lead to significant en route socioeconomic impacts because total expenditures for transportation related to depleted UF_6 would probably be small compared with expenditures related to total shipments of all other goods for any of the routes that might be used. The analysis might also have considered the socioeconomic impacts of potential accidents, particularly for depleted UF_6-related transportation activities. However, because it is unlikely that any potential accident would release large quantities of hazardous or radioactive material into the environment, accidents would be expected to create only minor local economic disruption, and substantial commitment of fiscal resources for accident remediation is unlikely to be necessary at any of the current storage sites or along transportation routes.

C.6.2 Technical Approach for the Analysis of Site-Specific and Representative Site Impacts

C.6.2.1 Regional Economic Impacts

The analysis of regional economic impacts used engineering cost data for facilities that would be constructed and operated for each option and input-output economic data for the ROI surrounding each storage site. The ROI at each site was defined as the counties in which 90% of site employees currently reside (see Chapter 3, Sections 3.1.8, 3.2.8, and 3.3.8). Additional data taken from data files of the U.S. Bureau of the Census (1994) and from regional economic information system data files of the U.S. Bureau of Economic Analysis (BEA) (1996a-c) were also used to forecast economic data at each site to provide the basis for the presentation of relative impacts.

To perform the analysis, engineering cost data for the construction and operation of each facility were taken from the cost data obtained from LLNL (1996). This report specifies cost and schedule data for the appropriate work breakdown structure elements, including the cost of materials, direct labor (installation) costs, and indirect labor (contractor field costs, contractor overhead and profit, architecture and engineering, construction management, and program management) costs.

Direct (on-site) employment and income impacts were then calculated on the basis of average total labor costs (i.e., fully loaded labor costs, including site overhead, contractor profit, and employee benefits) in each category. Estimates of direct income impacts were calculated by adjusting average fully loaded labor costs to exclude the various components of site overhead, state and federal income taxes, and other payroll deductions. This process produces a measure of disposable wage and salary income that would likely be spent in the regional economy at each of the sites.

Indirect (off-site) impacts were based on detailed item-specific procurement data for material and adjusted direct and indirect labor costs. Cost information was associated with the relevant Standard Industrial Classification (SIC) codes and construction and operation schedule information to provide estimates of procurement and wage and salary expenditures for each sector in the local economy for the year in which expenditures would be made. Information on the expected pattern of local and nonlocal procurement for the various materials and labor expenditures by SIC code were then calculated on the basis of local shares of national employment in each material and labor procurement category and information provided for each site. Expenditures by SIC code by year occurring in the ROI at each site were then mapped into the BEA sectors used in an IMPLAN input-output model (Minnesota IMPLAN Group, Inc. 1994) specified for the ROI at each site (see Section C.6.2.2). Each model was used to produce employment and income multipliers for each sector where procurement and labor expenditures occur. Indirect impacts were then calculated by multiplying expenditures in each sector by the input-output multipliers produced by the model for the ROI at each site.

Site-specific and representative site impacts are presented in terms of (1) the direct, indirect, and total employment impacts of each option; (2) the direct and total income impacts of each option; and (3) the relative employment impact of each option, or the magnitude of the absolute impact compared to the growth in the local economic employment baseline. Construction impacts for each option are presented for the peak construction year. Operations impacts are generally presented as annual averages, except for continued cylinder storage, for which peak operation year values are presented.

C.6.2.2 Description of the Regional Economic Impact Assessment Model

The analysis used county-level IMPLAN input-output economic data (Minnesota IMPLAN Group, Inc. 1994) to measure the regional economic impacts for the three representative sites for applicable options. The IMPLAN input-output model is a microcomputer-based program that allows construction of input-output models for counties or combinations of counties for any location in the United States. Input-output data are the economic accounts of any given region and show the flow of commodities to industries from producers and institutional consumers. The accounts also show consumption activities by workers, owners of capital, and imports from outside the region. The model contains 528 sectors, representing industries in agriculture, mining, construction, manufacturing, wholesale and retail trade, utilities, finance, insurance and real estate, and consumer and business services. The model also includes information for each sector on employee compensation; proprietary and property income; personal consumption expenditure; federal, state, and local expenditure; inventory and capital formation; and imports and exports. The model can be used to produce accurate estimates of the impact of changes in expenditures in specific local activities on employment and income in any given year. The analysis of regional economic impacts uses the model to calculate multipliers for each sector in the ROI at each site for which procurement and wage and salary expenditures would be likely to occur. These multipliers were calculated for the year 1993, the latest year available at the time the analysis was undertaken.

C.6.2.3 Impacts on Population

Construction and operation of continued storage, cylinder preparation, and long-term storage options would likely lead to population in-migration into the ROI surrounding each of the representative sites. In-migration would be both direct, related to new employment created on site, and indirect, related to changes in employment opportunities in the ROI as a whole. The number of direct employees in-migrating to each site was based on information on employment in existing DOE programs and on the level of contractor support at each site. Indirect in-migration that would occur for each ROI was calculated by using assumed in-migration rates at each site associated with changes in employment in the local industries most significantly affected indirectly by construction and operation expenditures for each option, with residual in-migration rates assumed for the remaining industries in the economy indirectly affected. Population impacts are presented in terms of (1) the absolute total (direct and indirect) in-migration impact of each option and (2) the relative population impact of each option, or the magnitude of the absolute impact compared to the growth in the local economic population baseline.

C.6.2.4 Impacts on Local Housing Markets

In-migration occurring with construction and operation at each facility has the potential to affect the local housing market in the ROI at the representative sites for each option. The analysis considered these impacts by estimating the increase in demand for housing units in each year of construction and operation based on the number of in-migrating workers to the area surrounding each of the representative sites and average household size. The results were compared to forecasts for housing supply and demand and owner-occupied and rental vacancy rates, for each year during construction and operation, based on information provided by the U.S. Bureau of the Census (1994) and in regional economic forecasts (BEA 1996a-c).

C.6.2.5 Impacts on Local Jurisdictions

Construction and operation of each facility would likely lead to some in-migration into the area surrounding each site, which would translate into changes in demand for educational services provided by school districts and for public services (police, fire protection, health services, etc.) provided by cities and counties. To assess the impacts on local jurisdictions, in-migration estimates (see Section C.6.2.3) were used as the basis for estimating impacts of revenues and expenditures for the various counties, cities, and school districts in each ROI. Revenue and expenditure data were based on the annual comprehensive financial reports produced by individual jurisdictions surrounding each site and on information provided by the U.S. Bureau of the Census (1994). Impacts are presented in terms of percentage change in forecasted revenues and expenditures for counties, cities, and school districts in the peak year of construction and in the first year of operations for each facility.

C.6.3 Technical Approach for the Analysis of Generic Site Impacts

The analysis of the socioeconomic impacts of the long-term storage in mines, manufacture and use, and disposal options was limited to the calculation of direct (on-site) employment and income impacts. No indirect impacts were calculated because the sites for these facilities have not been determined. The calculation of direct impacts was based on similar engineering cost information provided by LLNL (1996, 1997) for each facility and used the same methods as described in Section 6.2.2. The impacts of long-term storage in mines, manufacture and use, and disposal are presented in terms of the absolute direct impacts of each option at the generic site. No relative impacts were calculated because the site for these options has not been determined. For the same reason, estimates of population in-migration, local housing market impacts, and impacts on local jurisdiction revenues and expenditures are not provided.

C.7 LAND USE

The assessment of potential land-use impacts for the continued storage, cylinder preparation, conversion, manufacturing and use, long-term storage, and disposal options was based on a determination of areal requirements and incompatibility. Where appropriate, the amount of land that would be required under each option was calculated as a percentage of existing or available land at the three representative sites. The potential for program options to result in land conversion, land-use conflicts, or incompatibility with existing site planning documents or controls was explored.

Conversion refers to the potential of an action to convert land from one type of use to another (e.g., from agricultural to commercial). The potential for program options to result in impacts to surrounding land use is discussed qualitatively and includes an examination of potential level-of-service traffic impacts. Levels of service are defined by the Transportation Research Board (1994) and describe service characteristics and thresholds of congestion for highways.

For purposes of analysis in this PEIS, general criteria for estimation of impacts were as follows: land-use requirement of less than 50 acres corresponds to negligible impacts, land-use requirement of between 50 and 200 acres corresponds to potential moderate impacts, and land-use requirement of greater than 200 acres corresponds to potential large impacts. The actual potential for land conversion in conflict with existing land-use plans and controls and/or traffic flow problems will be determined during the Phase II analyses and NEPA reviews. Potential impacts to prime farmland will also be assessed in the site-specific tier of NEPA documentation that will accompany facility site selection.

No land-use impacts beyond respective site boundaries would be expected from the off-site transport aspect of the various management options under consideration. Any commitment of land at existing facilities that would be necessary for the off-site transport of UF_6, oxide, or uranium by-products is expected to be so small that no impacts would result.

C.8 ENVIRONMENTAL JUSTICE

C.8.1 Background

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," was issued by President Clinton in February of 1994 and directs federal agencies to incorporate environmental justice into all agency missions (U.S. President 1994). Under Executive Order 12898, federal agencies are directed to identify and address, as appropriate, high and adverse human health or environmental effects caused by agency programs, policies, or actions that disproportionately impact minority or low-income populations. Environmental justice refers to the equal and fair application of all environmental laws, regulations, and policies to all races, cultures, and income levels. The goal of the Executive Order is to ensure that no federal agency program, policy, or action results in impacts that affect minority or low-income populations to a greater degree than would be expected for the general population.

Executive Order 12898 directed the Administrator of the U.S. Environmental Protection Agency to establish an interagency working group (called the Federal Working Group on Environmental Justice) to develop criteria for identifying disproportionately high and adverse human health or environmental effects and to assist every federal agency in developing an environmental justice strategy. The Working Group, in coordination with the Council on Environmental Quality, has issued definitions to describe disproportionately high and adverse human health effects and disproportionately high and adverse environmental impacts as they apply to NEPA (Council on Environmental Quality 1997). DOE has also issued interim guidance for implementation of the Executive Order (DOE 1995e), and EPA has issued guidance for incorporating environmental justice concerns in EPA's NEPA activities (EPA 1998b).

C.8.2 Methodology

A determination of the potential for a given project or action to result in environmental justice impacts requires (1) an examination of the composition of the population residing within a defined zone of impact and (2) the existence of high and adverse human health effects or impacts resulting from the project or action under analysis. The potential for a given project or action to unfairly or "disproportionately" affect a particular segment of the affected population can only be determined after the minority and low-income populations that make up all or a portion of the affected population have been defined and identified. Once these populations have been defined and identified, high and adverse human health effects, if any, can be examined in the context of their likelihood to disproportionately affect minority or low-income populations.

The analysis of potential environmental justice impacts was limited to site-specific options because such an analysis requires an examination of the composition of a specific local population. Surrogate populations cannot be substituted for facilities that have not been specifically sited or located.

C.8.2.1 Definitions

The following definitions were used in the analysis of potential environmental justice impacts and were derived from the U.S. Census Bureau and the Working Group's definitions:

- *Census Tract* — An area usually containing between 2,500 and 8,000 persons that is used for organizing and monitoring census data. The spatial dimensions of census tracts vary widely, depending on population settlement density. Census tracts do not cross county borders.

- *Disproportionately High and Adverse Environmental Impact* — A deleterious environmental impact determined to be unacceptable or above generally accepted norms. A disproportionately high impact refers to an environmental hazard with a risk or rate of exposure for a low-income or minority population that exceeds the risk or rate of exposure for the general population.

- *Disproportionately High and Adverse Human Health Effects* — Any human health effect from exposure to environmental hazards that exceeds generally accepted levels of risk and affects low-income and minority populations at a rate that appreciably exceeds the rate for the general population. Adverse health effects were measured in risks and rates that could result in LCFs as well as nonfatal adverse impacts to human health.

- *Low-Income Population* — Persons of low-income status. Low-income status was based on U.S. Census Bureau data definitions of individuals living below the poverty line. The poverty line is defined by a statistical threshold that considers family size and income. For 1990, the poverty line threshold for a family unit consisting of four individuals was $12,674 (based on 1989 income). For purposes of this analysis, low-income population consists of any census tract located within a 50-mile (80-km) radius of a storage site that has a low-income population proportion greater than the respective state average.

- *Minority Population* — Persons classified by the U.S. Bureau of the Census as Negro/Black/African-American, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, or other nonwhite, based on self-classification by individuals according to the race with which they most closely identify. To avoid double-counting minority Hispanic persons (Hispanics can be of any race), only white Hispanics were included in the tabulation of minorities. Nonwhite Hispanics had already been counted under their respective minority classification (Black, American Indian, etc.). For purposes of this analysis, a minority population consists of any census tract located within a 50-mile (80-km) radius of a storage site that has a minority population proportion greater than the respective state average.

C.8.2.2 Identification and Illustration of Minority and Low-Income Populations

Demographic information obtained from the U.S. Bureau of the Census was used to profile the population residing within a 50-mile (80-km) radius of each current storage site. A 50-mile (80-km) radius was selected because it would capture virtually all of the human health risks and environmental impacts that could potentially occur. For each current storage site, a geographic information system based on 1990 Census Bureau *Tiger Line Files* and Summary Tape Files 1 and 3A was utilized to generate maps illustrating minority and low-income populations residing within the 50-mile (80-km) zone of impact surrounding each site (U.S. Bureau of the Census 1992a-c).

The unit of analysis was the census tract. For those census tracts only partially located inside a 50-mile (80-km) radius of a given site, an even population distribution was assumed, and the population was calculated as a proportion of the tract area physically located within the 50-mile (80-km) radius (i.e., if 50% of the census area was inside of the 50-mile (80-km) radius, then 50%

of its population was counted). The maps are presented as Figures C.1 through C.3 and depict the distribution of minority and low-income census tracts within a 50-mile (80-km) radius of each site. Information regarding the proportion of the total population residing within 50 miles (80 km) of each site that is minority or low-income accompanies each figure.

For each current storage site, the proportion thresholds for determining the low-income and/or minority status of a census tract were based on the proportion of low-income and minority populations residing within the state where the storage site was located. If the 50-mile (80-km) radius around a particular current storage site included a portion of another state or states, a weighted average based on all the affected state low-income and minority population proportions was assigned. Other reference threshold proportions were considered (i.e., national, multistate regional), but state population proportions were chosen because they tend to present a more accurate portrayal of the affected population.

C.8.2.3 Impact Approach

The analysis of potential environmental justice impacts resulting from continued storage and cylinder preparation was based on the conclusions drawn in the risk assessment of human health effects (radiological and chemical) and a review of environmental impacts presented in discussions of other technical areas such as air quality, water quality and soils, socioeconomics, and ecological resources. The analysis of health effects included an examination of risks to the off-site population associated with normal facility operations and accidents. On-site worker populations were not included in the analysis because minority population proportion information for each site was not available and low-income status for workers, regardless of site, could not be determined. If conclusions drawn in the health risk assessment indicated negligible or low risks to the general population residing within a 50-mile (80-km) radius of any of the three storage sites, then no particular subset of the general population, including minorities and low-income persons, was assumed to experience high and adverse health effects. Consequently, no disproportionate impacts (i.e., environmental justice impacts) would occur. Likewise, if the review of environmental impacts across the other technical areas indicated that impacts were negligible or low within a 50-mile (80-km) radius of a particular site, then no environmental justice impacts would result because the potential for high and adverse impacts to disproportionately affect minority or low-income populations would be essentially removed.

An assessment of human health risks for persons or population groups residing within 50 miles (80 km) of a storage site who rely on local plants or animals for a portion of their food supply was not included in this analysis. A comprehensive analysis that includes an evaluation of an affected population's dietary and consumption habits would be considered in the site-specific tier of NEPA documentation that would follow a Depleted Uranium Hexafluoride Management Program decision.

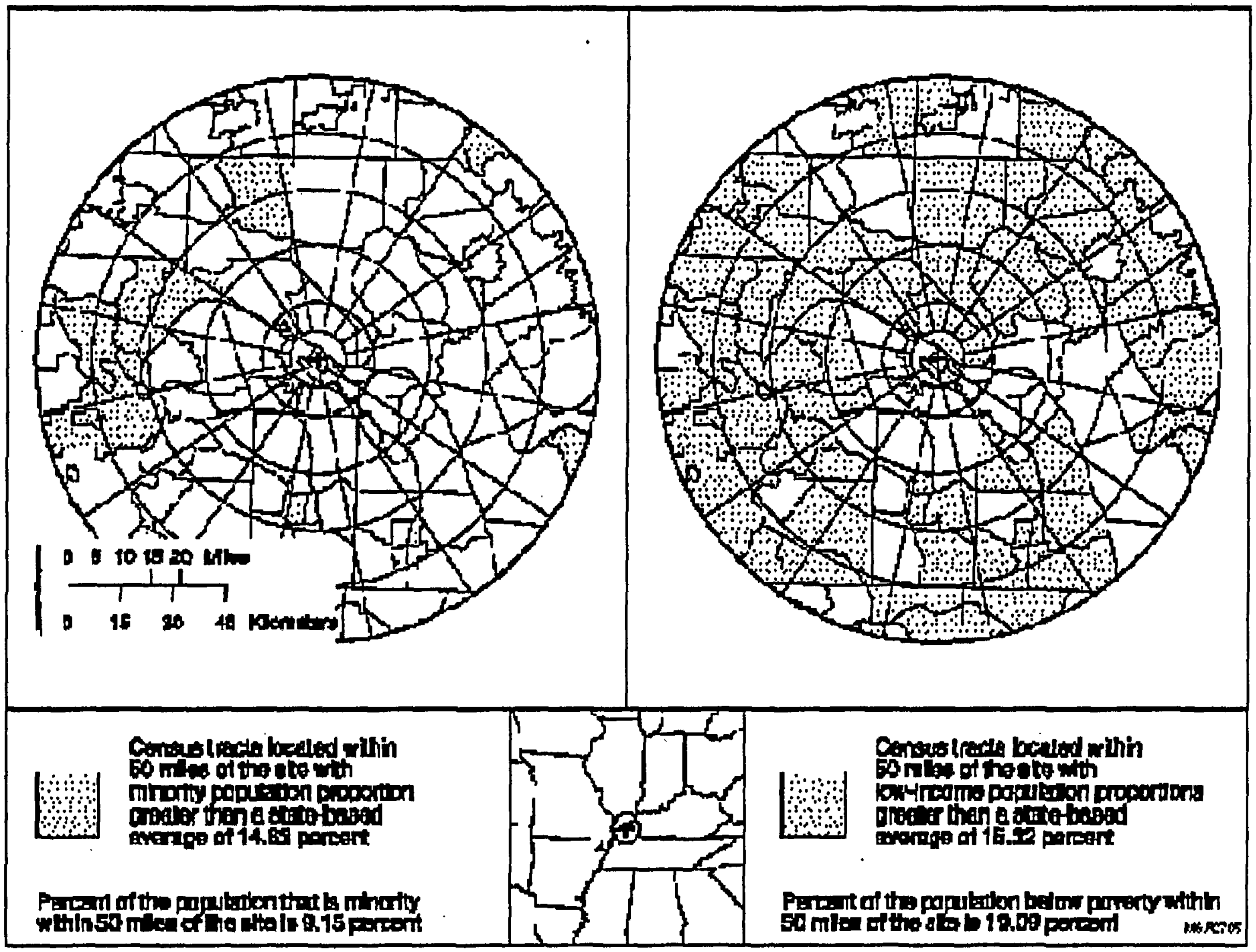

FIGURE C.1 Distribution of Minority and Low-Income Census Tracts within a 50-Mile Radius of the Paducah Site

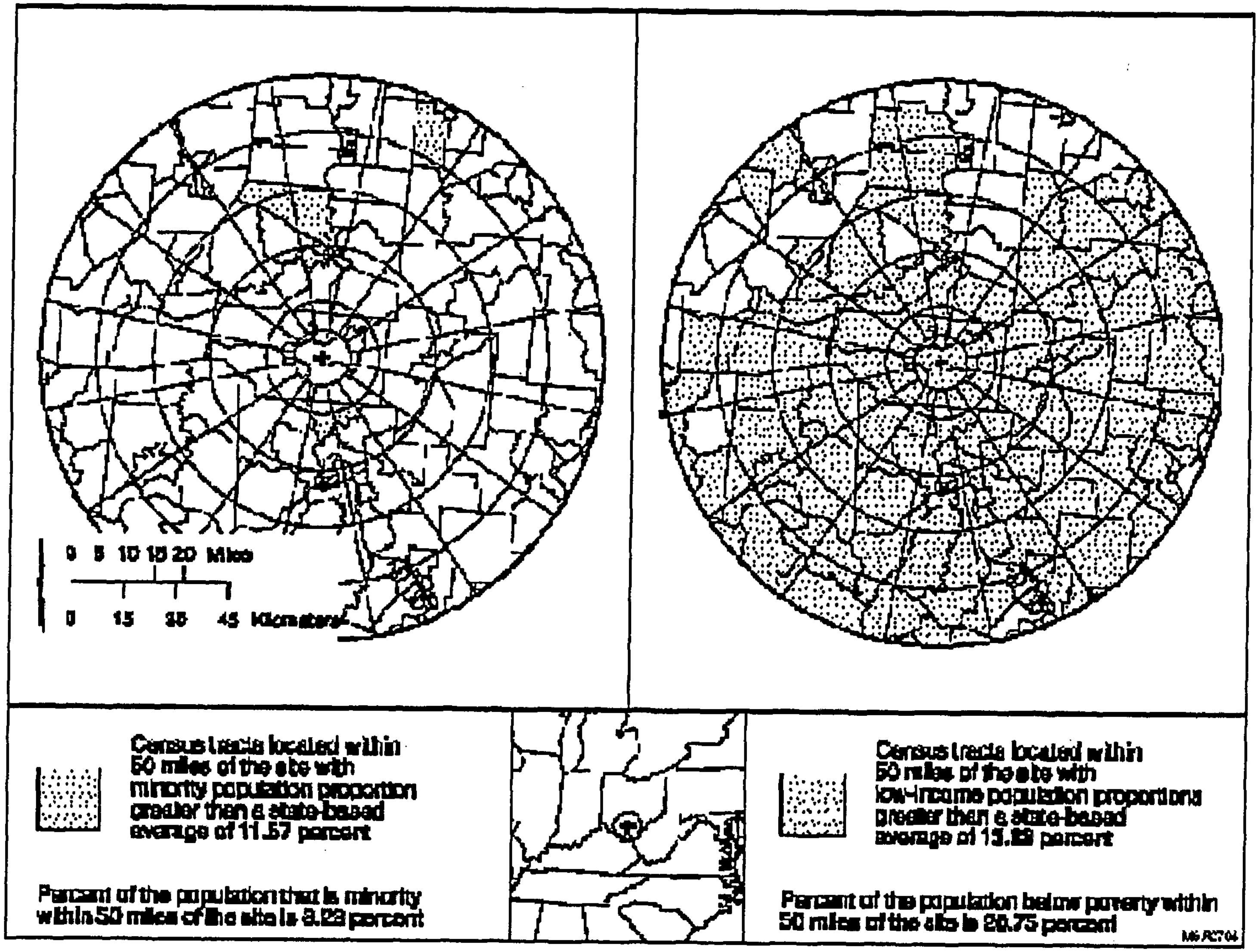

FIGURE C.2 Distribution of Minority and Low-Income Census Tracts within a 50-Mile Radius of the Portsmouth Site

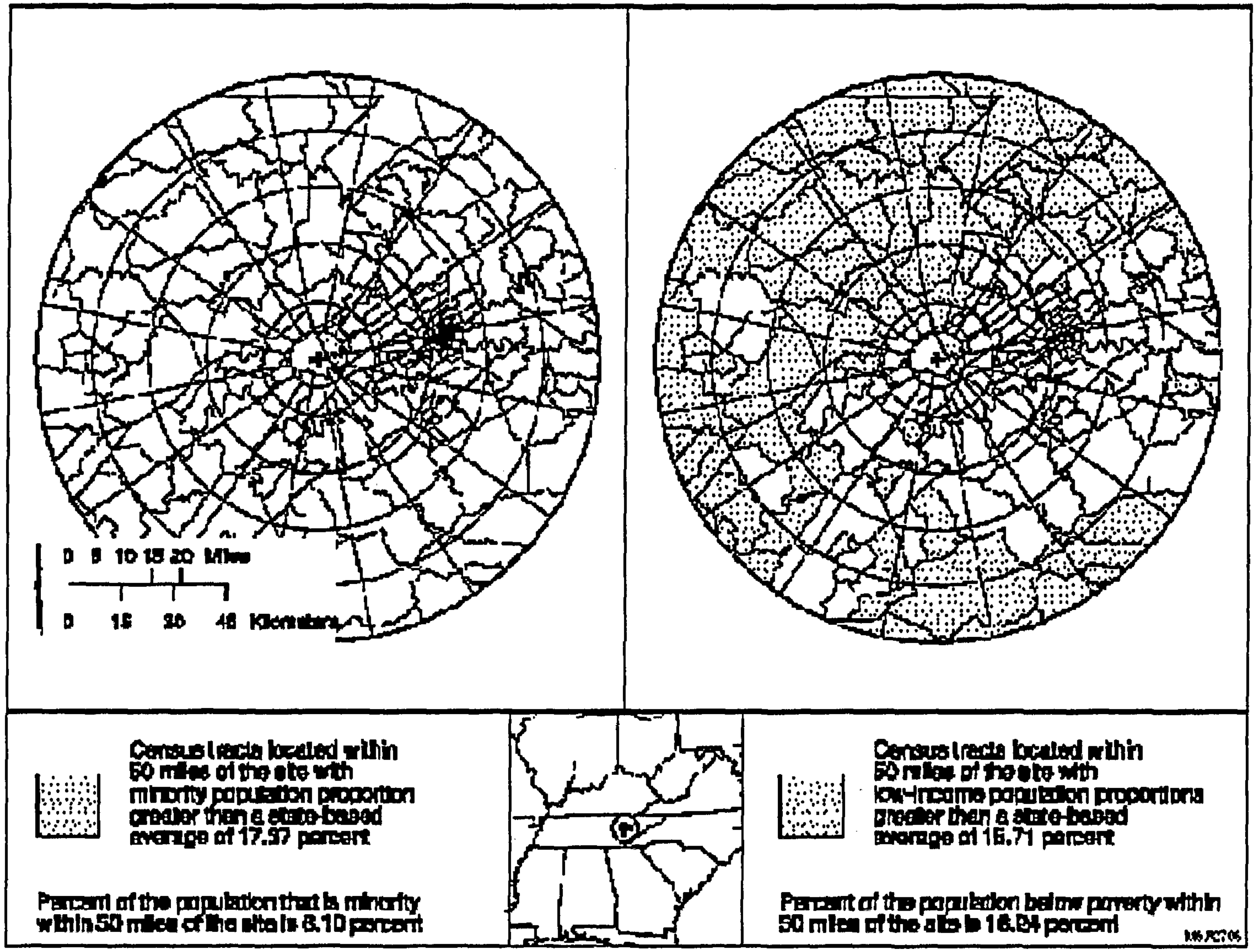

FIGURE C.3 Distribution of Minority and Low-Income Census Tracts within a 50-Mile Radius of the K-25 Site

An assessment of potential environmental justice impacts resulting from transportation accidents was not conducted for this analysis. Although environmental justice impacts could occur within a given transportation corridor following an accident, a site-specific (i.e., corridor-specific) demographic analysis cannot be conducted because the transportation analysis did not predict the location of accidents, and because it is impossible to predict reliably who will be involved in transportation accidents. There is no reason to believe that impacts of transportation accidents will affect minority or low-income populations disproportionately.

C.8.2.3.1 Screening Criteria

To evaluate the potential for continued storage to result in disproportionate impacts to minority and low-income populations, screening criteria based on the assessment of radiological and chemical risks were used to determine what sites, if any, would require further analysis. These criteria included:

- A dose to the general public MEI exceeding 100 mrem/yr under normal operations.
- An expected LCF equal to or greater than 1 from radioactive sources under accident conditions.
- A hazard index for the MEI equal to or greater than 1 from chemical sources under normal operations.
- An expected incidence of irreversible adverse effects equal to or greater than 1 from accidental chemical releases, when accident frequency categories and duration of operations were considered.

In assessing accident risks, the consequence of an accident must be considered as a function of the expected frequency of the accident. For example, if a particular accidental chemical release was projected to result in 100 fatalities but was expected to occur only once in 10,000 years (also expressed as 1×10^{-4} per year), then expected annual fatalities could be calculated by multiplying the consequence (100 fatalities) of the accident by the expected accident frequency (1×10^{-4} per year), which yields 0.01 expected fatalities per year from the particular accident analyzed. The PEIS assessment of human health risk categorizes accident frequencies according to the likelihood of occurrence. A discussion of risk conversion factors, accident consequences, and frequency categories is presented in Chapter 4.

The hazard index for the MEI (see Appendix D, Table D.5) was used to determine health effects from chemical sources under normal operations. This methodology is discussed in greater detail in Section C.5.

To determine expected LCFs from radiological source accidents, the LCF risk for the general public (see Appendix D, Table D.8) was multiplied by the frequency category value of the worst accident scenarios to determine maximum effects. For purposes of this analysis, the midrange value of the frequency category under consideration was used (i.e., 10^{-5} for the frequency category that is defined by a range of 10^{-4} to 10^{-6}).

The expected incidence of irreversible adverse effects from accidental chemical releases was determined by multiplying the number of persons projected to be affected under the worst accidental release scenario by the midrange value of the appropriate frequency category value, and then multiplying that total by the number of years under consideration. Although the depleted UF_6 PEIS risk assessment projected possible radiological and chemical human health effects from disposal beyond the year 2039, such effects could not be included in the analysis of potential environmental justice impacts because the composition of the population residing within 50 miles (80 km) of a site cannot be projected with accuracy beyond the year 2040. Current minority and low-income population proportions for each site were assumed to the year 2039.

C.8.2.3.2 Demographic Analysis

If projected human health effects exceeded screening criteria limits at any of the three sites, a demographic analysis would be conducted. For radiological impacts from normal operations, the 50-mile (80-km) radius surrounding each site would be divided into sectors and blocks for a higher resolution examination. A grid consisting of pie-shaped sectors (see Figures C.1 through C.3) positioned 360° around the centroid of the storage yards and six concentric circles (with interval sizes of 5 and 10 miles [8 and 16 km]) radiating outward would be used to break the 50-mile (80-km) zone of impact surrounding each site into sectors and blocks. A block consists of the portion of a preshaped sector bounded by (or located between) two concentric circles.

If the dose to the general public MEI from radiological sources under normal operations equaled or exceeded 100 mrem/yr, a block dose value would be assigned to each census tract in the affected sector block or blocks. A comparative analysis of the tracts receiving the highest doses (upper 10%) would be conducted to determine the proportion of tracts that were minority or low-income. If the proportion of minority or low-income tracts in the upper 10% was higher than the proportion of minority or low-income tracts inside the 50-mile (80-km) zone of impact surrounding an affected site, then an environmental justice impact would be declared.

For chemical releases associated with routine operations that resulted in a hazard index equal to or greater than 1 for the MEI, the block containing the MEI would be examined for population composition. If the MEI block was composed of minority or low-income census tracts, then a declaration of potential disproportionate health impacts would be included in the impact discussion for the appropriate site. In cases where the MEI block would contain more than one census tract, the tract closest to the site would be used to determine potential disproportionality.

If screening criteria were exceeded for radiological and chemical accident releases, a population composition analysis would be conducted for census tracts in all sectors and blocks within a 5-mile (8-km) radius of the release source. A 5-mile (8-km) limit was chosen because release plume analysis indicated that at least 95% of the effects from accidental releases would occur within 5 miles (8 km) of the release point. Although an accidental release would have the greatest potential to affect persons residing in sectors and blocks located downwind from the release, a 5-mile (8-km) radius provides a conservative means to estimate potential disproportionate effects, regardless of wind direction at the time of release. If the proportion of minority or low-income census tracts located within a 5-mile (8-km) radius of release points was higher than the proportion for the entire 50-mile (80-km) zone of impact surrounding the site, then a declaration of potential disproportionate health impacts would be included in the impact discussion for the affected site.

C.9 TRANSPORTATION

The technical approach for conducting the transportation risk assessment was developed following an extensive review of the literature and existing NEPA documentation for federal actions involving transportation of radioactive materials. The transportation risk assessment approach for the PEIS is consistent with the approach developed to support the WM PEIS (DOE 1997). Recently, the same approach was also applied in the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (INEL EIS; DOE 1995a) and in the *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (DOE 1996a). The basic assessment approach has been previously reviewed by DOE and by representatives of DOE, including a transportation technical review group whose mission was to evaluate available analytical methods for the INEL EIS. The review group included technical representatives of Argonne National Laboratory; Bettis Atomic Power Laboratory (Naval Reactors); and Savannah River Site, Hanford Site, and Science Applications International Corporation-Idaho (preparers of the INEL EIS). In addition, comments on the approach were also solicited from the NRC for the WM PEIS. The approach is described below.

The approach for the hazardous chemical component of the transportation risk assessment was similar to the radiological approach. However, no cargo-related impacts were assessed under routine conditions.

C.9.1 Scope of the Analysis

The transportation risk assessment for management of depleted UF_6 involved estimating the potential human health risks during transportation of depleted uranium in different forms. Risks were estimated from both "vehicle-related" and "cargo-related" causes. Vehicle-related risks result from the nature of transportation itself, independent of the radioactive characteristics of the cargo. For example, increased levels of pollution from vehicular exhaust emissions may affect human health. Similarly, accidents during transportation may cause injuries and fatalities from physical trauma. On the other hand, cargo-related risk generally refers to risks that would be attributable to the characteristics of the shipment cargo. The cargo-related risks from the transportation of depleted uranium would be caused by exposure to ionizing radiation. Exposures to radiation occur under both routine (i.e., incident-free) transportation and during accident conditions.

For each of the alternatives considered for managing depleted UF_6 that would involve transportation, cargo-related and vehicle-related risks were calculated for shipments between each of the origin and destination sites (see Table C.2). Options evaluated included the shipment of depleted UF_6 from its current location(s) to storage or conversion facilities; the shipment of UO_2 from conversion facilities to storage, cask manufacture, or disposal facilities; the shipment of U_3O_8 from conversion facilities to storage or disposal facilities; the shipment of depleted uranium metal from conversion facilities to cask manufacture facilities; and the shipment of low-level radioactive waste (LLW) from conversion and manufacturing facilities to LLW disposal sites. The number of shipments between each pair of origin and destination sites was calculated for truck and rail modes by using projected site-specific inventories.

Unit risks per kilometer were developed because the locations of the conversion, storage, manufacturing, end user, and disposal facilities have not been determined. These unit risks were based on national average data derived from the data discussed below for route-specific data. The application of these data is discussed in the PEIS.

The technical approach for estimating transportation risks uses several computer models and databases. Transportation risks were assessed for both routine and accident conditions. For the routine assessment, risks were calculated for the collective populations of all potentially exposed individuals, as well as for a small set of MEI receptors. The accident assessment consisted of two components: (1) an accident risk assessment, which considered the probabilities and consequences of a range of possible transportation-related accidents, including low-probability accidents that have high consequences, and high-probability accidents that have low consequences; and (2) an accident consequence assessment, which considered only the radiological consequences of low-probability accidents that were postulated to result in the largest releases of radioactive material. The release fractions used in the accident risk assessment were based on the data in NUREG-0170 (NRC 1977a) and independent engineering analyses.

C.9.2 Routine Risk Assessment Method

The RADTRAN 4 computer code (Neuhauser and Kanipe 1993) was used for the routine and accident cargo-related risk assessments to estimate the radiological impacts to collective populations. RADTRAN 4 was developed by Sandia National Laboratories to calculate population risks associated with the transportation of radioactive materials by a variety of modes, including

TABLE C.2 Potential Shipments of Radioactive Material Analyzed in the PEIS for Depleted UF_6

Material	Origin	Destination
Depleted UF_6	Gaseous diffusion plants site storage yards	Storage or conversion facilities
UO_2	Conversion facilities	Storage, manufacturing, or disposal facilities
Uranium oxide cask	Manufacturing facilities	End user
U_3O_8	Conversion facilities	Storage or disposal facilities
Depleted uranium metal	Conversion facilities	Manufacturing facilities
Depleted uranium metal cask	Manufacturing facilities	End user
Low-level waste (depleted uranium-contaminated material)	Conversion, manufacturing, and cylinder transfer and treatment facilities	Low-level waste disposal sites
Mixed waste	Conversion, manufacturing, and cylinder transfer and treatment facilities	Mixed waste treatment

truck, rail, air, ship, and barge. The code has been used extensively for transportation risk assessments since it was issued in the late 1970s and has been reviewed and updated periodically.

As a complement to the RADTRAN calculations, the RISKIND computer code (Yuan et al. 1995) was used to estimate scenario-specific doses to MEIs for both routine operation and accident conditions and to estimate population impacts for the accident consequence assessment. The RISKIND computer code was originally developed for the DOE Office of Civilian Radioactive Waste Management specifically to analyze radiological consequences to individuals and population subgroups from the transportation of spent nuclear fuel and is now capable of analyzing the transport of other radioactive materials.

Routine risks from hazardous chemical shipments would not be expected. The shipping packages were assumed not to leak during routine transportation operations.

C.9.2.1 Collective Population Risk

The radiological risk associated with routine transportation results from the potential exposure of people to low-level external radiation in the vicinity of loaded shipments. Because the radiological consequences (dose) occur as a direct result of normal operations, the probability of routine consequences is taken to be unity in the RADTRAN 4 code. Therefore, the dose risk is equivalent to the estimated dose.

For routine transportation, the RADTRAN 4 computer code considers all major groups of potentially exposed persons. The RADTRAN 4 calculations of risk for routine highway and rail transportation include exposures of the following population groups:

- ***Persons along the Route (Off-Link Population).*** Collective doses were calculated for all persons living or working within 0.5 mile (0.8 km) of each side of a transportation route. The total number of persons within the 1-mile (1.6-km) corridor was calculated separately for each route considered in the assessment.

- ***Persons Sharing the Route (On-Link Population).*** Collective doses were calculated for persons in all vehicles sharing the transportation route. This group includes persons traveling in the same or opposite directions as the shipment, as well as persons in vehicles passing the shipment.

- ***Persons at Stops.*** Collective doses were calculated for people who might be exposed while a shipment was stopped en route. For truck transportation, these stops include stops for refueling, food, and rest. For rail transportation, stops were assumed to occur for purposes of classification.

- ***Crew Members.*** Collective doses were calculated for truck and rail transportation crew members involved in the actual shipment of material. Workers involved in loading or unloading were not considered.

The doses calculated for the first three population groups were added together to yield the collective dose to the general public; the dose calculated for the fourth group represents the collective dose to workers. The RADTRAN 4 models for routine dose are not intended for use in estimating specific risks to individuals.

The RADTRAN 4 calculations for routine dose are based on generically expressing the dose rate as a function of distance from a point source (Neuhauser and Kanipe 1993). Associated with the calculation of routine doses for each exposed population group are parameters such as the radiation field strength, the source-receptor distance, the duration of exposure, vehicular speed, stopping time, traffic density, and route characteristics such as population density. The RADTRAN manual contains derivations of the equations and descriptions of these parameters (Neuhauser and Kanipe 1993).

For the depleted UF_6 PEIS, the collective routine risks were calculated for each set of shipments as follows. Impacts were estimated on a unit risk per kilometer traveled basis because the origin and destination sites for the alternatives have not yet been determined. As such, RADTRAN 4 was used to calculate the collective risks to workers and the public on the basis of accident rates and population densities, which are summarized in Biwer et al. (1997), and representative radiological and physical properties of the transported material. The collective risks presented incorporated the total number of shipments over the life of the project (20 years in most cases). For a given option, the number of shipments for each type of material was determined by the annual input or output capacities for the facility under consideration (conversion, treatment, storage, manufacture, or disposal). To give the reader a perspective on the routine risks involved, results were presented for shipment distances of 250, 1,000, and 5,000 km.

C.9.2.2 Maximally Exposed Individual Risk

In addition to the assessment of the routine collective population risk, the risk to MEIs was estimated for a number of hypothetical exposure scenarios by using RISKIND. The receptors included transportation crew members, departure inspectors, and members of the public exposed during traffic delays, while working at a service station, or while living near a facility.

The dose to each MEI considered was calculated with RISKIND for an exposure scenario defined by a given distance, duration, and frequency of exposure specific to that receptor. The distances and durations of exposure were similar to those given in previous transportation risk assessments (DOE 1990, 1995a, 1996a) The scenarios were not meant to be exhaustive but were selected to provide a range of potential exposure situations.

The RISKIND external dose model considers direct external exposure and exposure from radiation scattered from the ground and air. RISKIND was used to calculate the dose as a function of distance from a shipment on the basis of the dimensions of the shipment (millirem per hour for stationary exposures and millirem per event for moving shipments). The code approximates the shipment as a cylindrical volume source, and the calculated dose includes contributions from secondary radiation scattering from buildup (scattering by the material contents), cloudshine (scattering by the air), and groundshine (scattering by the ground). The dose rate curve (relative dose rate as a function of distance) specific to depleted uranium was determined by using the MicroShield code (Negin and Worku 1992; see Section C.4.1.4) for input into RISKIND. As a conservative measure, credit for potential shielding between the shipment and the receptor was not considered.

C.9.2.3 Vehicle-Related Risk

Vehicle-related health risks resulting from routine transportation might be associated with the generation of air pollutants by transport vehicles during shipment and would be independent of the radioactive or chemical nature of the shipment. The health endpoint assessed under routine transportation conditions was the excess latent mortality due to inhalation of vehicular emissions. These emissions consist of particulate matter in the form of diesel engine exhaust and fugitive dust raised from the road/railway by the transport vehicle.

Risk factors for pollutant inhalation in terms of latent mortality have been generated by Rao et al. (1982). These risk factors are 1.6×10^{-7}/mile (1×10^{-7} mortality/km) and 2.1×10^{-7}/mile (1.3×10^{-7} mortality/km) for truck and rail travel, respectively, in urban areas. The risk factors are based on regression analyses of the effects of sulfur dioxide and particulate releases from diesel exhaust on mortality rates. Excess latent mortalities were assumed to be equivalent to LCFs. Vehicle-related risks from routine transportation were calculated for each shipment by multiplying the total distance traveled in urban areas by the appropriate risk factor. This method has been used in several reports to calculate risks from routine transportation of radioactive wastes (DOE 1990, 1995a, 1996a).

The routine vehicle-related health risks were considered to be incremental risks. The risk of mortality from air pollutants is thought to occur after some threshold air concentration is exceeded (EPA 1993b). In addition, the air concentration thresholds were derived when considering chronic exposure over extended periods of time. Such higher air pollutant concentrations exist primarily in populated urban areas, where the increase in pollutant levels by a single shipment would incrementally add to the mortality risk. Rural and suburban population areas generally do not have such high air pollutant levels, and the relatively small amount added as the result of a single shipment would not be enough to raise air concentrations above threshold levels for injury for even a brief period of time.

C.9.3 Accident Assessment Methodology

As discussed in the previous section, the radiological transportation accident risk assessment uses the RADTRAN 4 code for estimating collective population risks and the RISKIND code for MEI and population consequences.

The hazardous chemical transportation accident risk assessment relies on the HGSYSTEM model (Post 1994a-b) for both the collective population and individuals. The model is a widely applied code recognized by the EPA for chemical accident consequence predictions.

The collective accident risk for each type of shipment was determined in a manner similar to that described for routine collective risks. Unit accident risks on a per kilometer traveled basis were first calculated for each type of shipment. As discussed in Chapter 4, the accident risk assessment uses national route average characteristics such as accident rates and population density information. In addition, the radiological, chemical, and physical properties of the material transported and its packaging characteristics were incorporated into the calculations. The collective accident risks presented incorporated the total number of shipments over the life of the project (20 years in most cases). For a given option, the number of shipments for each type of material was determined by the annual input or output capacities for the facility under consideration (conversion, treatment, storage, manufacture, or disposal). To give the reader a perspective on the accident risks involved, results were presented for shipment distances of 250, 1,000, and 5,000 km.

C.9.3.1 Radiological Accident Risk Assessment

The risk analysis for potential accidents differs fundamentally from the risk analysis for routine transportation because occurrences of accidents are statistical in nature. The accident risk assessment is treated probabilistically in RADTRAN 4 and in the HGSYSTEM approach used to estimate the hazardous chemical component of risk. Accident risk is defined as the product of the accident consequence (dose or exposure) and the probability of the accident occurring. In this respect, RADTRAN 4 and the HGSYSTEM approach both estimate the collective accident risk to populations by considering a spectrum of transportation-related accidents. The spectrum of accidents was designed to encompass a range of possible accidents, including low-probability accidents that have high consequences, and high-probability accidents that have low consequences (such as "fender benders"). The total collective radiological accident dose risk was calculated as:

$$R_{Total} = D \times A \times \sum_{i=1,n} (P_i \times C_i) \quad ,$$

where:

R_{Total} = total collective dose risk for a single shipment distance *D* (person-rem),

D = distance traveled (km),

A = accident rate for transport mode under consideration (accidents/km),

P_i = conditional probability that the accident is in severity category *I*, and

C_i = collective dose received (consequence) should an accident of severity category *I* occur (person-rem).

The results for collective accident risk can be directly compared with the results for routine collective risk because the latter results implicitly incorporate a probability of occurrence of one if the shipment takes place.

The RADTRAN 4 calculation of collective accident risk employs models that quantify the range of potential accident severities and the responses of transported packages to accidents. The spectrum of accident severity is divided into a number of categories. Each category of severity is assigned a conditional probability of occurrence — that is, the probability that an accident will be of a particular severity if an accident occurs. The more severe the accident, the more remote the chance of such an accident. Release fractions, defined as the fraction of the material in a package that could be released in an accident, are assigned to each accident severity category on the basis of the physical and chemical form of the material. The model takes into account the mode of transportation and the type of packaging being considered. The accident rates, the definition of accident severity categories, and the release fractions used in this analysis are discussed further in Biwer et al. (1997). The approach for hazardous chemicals incorporates the same accident severity categories and release fractions used by RADTRAN 4.

For accidents involving the release of radioactive material, RADTRAN 4 assumes that the material is dispersed in the environment according to standard Gaussian diffusion models. For the risk assessment, default data for atmospheric dispersion were used, representing an instantaneous ground-level release and a small-diameter source cloud (Neuhauser and Kanipe 1993). The calculation of the collective population dose following the release and dispersal of radioactive material includes the following exposure pathways:

- External exposure to the passing radioactive cloud,
- External exposure to contaminated ground,
- Internal exposure from inhalation of airborne contaminants, and
- Internal exposure from the ingestion of contaminated food.

For the pathway of ingestion, national-average food transfer factors, which relate the amount of radioactive material ingested to the amount deposited on the ground, were calculated in accordance with the methods described by NRC Regulatory Guide 1.109 (NRC 1977b) and were used as input to the RADTRAN code. Doses of radiation from the ingestion or inhalation of radionuclides were calculated by using standard dose conversion factors (DOE 1988a-b).

C.9.3.2 Chemical Accident Risk Assessment

The risks from exposure to hazardous chemicals during transportation-related accidents can be either acute (result in immediate injury or fatality) or latent (result in cancer that would present itself after a latency period of several years). Both population risks and risks to the MEI were evaluated for transportation accidents. The acute health endpoint, potential irreversible adverse effects, was evaluated for the assessment of cargo-related population impacts from transportation accidents. Accidental releases during transport of various uranium compounds (e.g., UF_6, UO_2, U_3O_8, uranium metal), HF, and ammonia were evaluated quantitatively.

The acute effects evaluated were assumed to exhibit a threshold nonlinear relationship with exposure; that is, some low level of exposure can be tolerated without inducing a health effect. To estimate risks, chemical-specific concentrations were developed for potential irreversible adverse effects. All individuals exposed at these levels or higher following an accident were included in the transportation risk estimates. In addition to acute health effects, the cargo-related risk of excess cases of latent cancer from accidental chemical exposures could be evaluated. However, none of the chemicals that might be released in any of the accidents would be carcinogenic. As a result, no predictions for excess latent cancers are presented in this report for accidental chemical releases.

Additionally, to address MEIs, the locations of maximum hazardous chemical concentration were identified for shipments with the largest potential releases. Estimates of exposure duration at those locations were obtained from modeling output and used to assess whether MEI exposure to uranium and other compounds exceeded the criteria for potential irreversible adverse effects.

The primary exposure route of concern with respect to accidental release of hazardous chemicals would be inhalation. Although direct exposure to hazardous chemicals via other pathways, such as ingestion or dermal absorption, would also be possible, these routes would be expected to result in much lower exposure than the inhalation pathway doses for the chemicals of concern in the depleted UF_6 PEIS. The likelihood of acute effects would be much less for the ingestion and dermal pathways than for inhalation.

The HGSYSTEM Version 3.0 model (Hanna et al. 1994) has a built-in source-term algorithm that is used to compute the rate, quantity, and type of atmospheric release of a hazardous air pollutant, including pool evaporation from a volatile organic liquid spill. The model is able to handle frequently encountered accidental releases from ruptured tanks, drums, and pipes. The model incorporates a chemical data library of physical and chemical properties (such as vapor pressure, boiling point, and molecular weight) for 30 chemical compounds. Physical properties of the chemical released, along with container content input, such as the container geometry and rupture characteristics (e.g., hole size), are used by HGSYSTEM to compute chemical release rate and duration. The risk assessment for hazardous chemicals assumed that organic liquid spills and particulate releases would be of short duration as liquid and solid (as respirable fraction) aerosols. The release fractions were estimated with the approach used for radionuclide releases. The risks associated with the consequences estimated with the HGSYSTEM code were computed separately with a risk quantification spreadsheet program.

C.9.3.3 Accident Consequence Assessment

Because predicting the exact location of a severe transportation-related accident is impossible when estimating population impacts, separate accident consequences were calculated for accidents occurring in rural, suburban, and urban zones of population density. Moreover, to address the effects of the atmospheric conditions existing at the time of an accident, two different atmospheric conditions were considered. The first case assumed neutral (i.e., unstable) atmospheric conditions, and the second assumed stable conditions.

The MEI for severe transportation accidents was considered to be located at the point of highest hazardous material concentration that would be accessible to the general public. This location was assumed to be 100 ft (30 m) or farther from the release point at the location of highest air concentration as determined by the HGSYTSTEM and FIREPLUME models. Only the shipment accident resulting in the highest contaminant concentration was evaluated for the MEI.

C.9.3.3.1 Radiological Accident Consequence Assessment

The RISKIND code was used to provide a scenario-specific assessment of radiological consequences of severe transportation-related accidents. Whereas the RADTRAN 4 accident risk assessment considers the entire range of accident severities and their related probabilities, the RISKIND accident consequence assessment focuses on accidents that result in the largest releases of radioactive material to the environment. Accident consequences were presented for each type of shipment that might occur under any given option for each alternative. The accident consequence assessment was intended to provide an estimate of the potential impacts posed by a severe transportation-related accident.

The severe accidents considered in the consequence assessment are characterized by extreme mechanical and thermal forces. In all cases, these accidents result in a release of radioactive material to the environment. The accidents correspond to those within the highest accident severity category, as described previously. These accidents represent low-probability, high-consequence events. The probability of accidents of this magnitude would be dependent on the number of shipments and the total shipping distance for the options considered; however, accidents of this severity would be expected to be extremely rare.

Severe accidents involving solid radioactive material that result in the highest impacts generally are related to fire. The fire acts to break down and distribute the material of concern. Air concentrations of radioactive contaminants at receptor locations following a hypothetical accident were determined by using the FIREPLUME model. On the basis of these air concentrations, RISKIND was used to calculate the radiological impacts for the accident consequence assessment.

The accident consequences were calculated for both local populations and MEIs. The population dose includes the population within 50 miles (80 km) of the site of the accident. The exposure pathways considered would be similar to those discussed previously for the accident risk assessment. Although remedial activities after the accident (e.g., evacuation or ground cleanup) would reduce the consequences of an accident, these activities were not given credit in the consequence assessment.

C.9.3.3.2 Chemical Accident Consequence Assessment

The HGSYSTEM model version 3.0 was used to estimate the potential consequences from severe hazardous chemical accidents. The FIREPLUME model was used to predict the consequences of transportation accidents involving fires. The HGSYSTEM model is described in Section C.9.3.2.

C.9.3.4 Vehicle-Related Accident Risk Assessment

The vehicle-related accident risk refers to the potential for transportation-related accidents that could directly result in fatalities not related to the cargo in the shipment. This risk represents fatalities from mechanical causes. National-average rates for transportation-related fatalities were used in the assessment. Vehicle-related accident risks were calculated by multiplying the total distance traveled by the rate for transportation-related fatalities. In all cases, the vehicle-related accident risks were calculated by using distances for round-trip shipment.

C.10 WASTE MANAGEMENT

C.10.1 General Methods

Impacts to the waste management resources at each of the sites were evaluated for the continued storage, cylinder preparation, conversion, manufacture and use, long-term storage, and disposal options. For the continued storage and cylinder preparation options, site-specific impacts were estimated on the basis of actual cylinder populations in the storage yards of the Paducah, Portsmouth, and K-25 sites. For the conversion and long-term storage options (except long-term storage in mines), the three current storage sites were used as representative locations. The analysis of site-specific and representative site impacts compared the volume throughputs resulting from normal activities at the waste management facilities at each site with the waste throughputs expected from the different options. Wastes were considered according to the standard categories of LLW, low-level mixed waste (LLMW), hazardous waste, and nonhazardous waste. In addition, waste streams were identified as to media type (e.g., solid or liquid) and the likely treatment (e.g., incineration, compaction, or sanitary discharge). Where new waste management facilities would be needed at a particular site, the impacts for waste management from construction of these facilities were also evaluated. The analysis for manufacturing and use, long-term storage in mines, and disposal options assumed generic, nonspecific environmental settings for the required activities.

For purposes of analysis for the generic options, the wastes generated at each site were compared with the total amount of waste generated nationwide in all DOE waste management activities. The comparison of waste generation rates with available capacity for depleted UF_6 waste (especially LLW) was limited primarily to the DOE waste management system. Currently three commercial facilities (Barnwell, South Carolina; Richland, Washington; and Envirocare in Utah) are accepting about 37,000 m^3/yr of commercial LLW, and DOE is disposing of about 65,000 m^3/yr of LLW at DOE facilities. DOE LLW generation is expected to increase to about 100,000 to 200,000 m^3/yr once environmental restoration operations begin. Commercial facilities that manage LLW have the capability to expand rapidly and may accept DOE LLW in the future if it can be managed profitably. Also, some of the depleted UF_6 wastes might not be considered DOE wastes (e.g., calcium fluoride [CaF_2] or magnesium fluoride [MgF_2] possibly generated during conversion processes, if the conversion were conducted by a private commercial enterprise).

The analysis also included the secondary waste streams associated with storage of treated or untreated waste and any secondary waste streams associated with the packaging or handling of treated wastes in preparation for disposal.

C.10.2 Data Requirements

For each option considered, projected annual generation volumes for the various waste types were compared with waste treatment volumes/disposal capacities projected from existing programs at the representative sites or projected to be available at the national level (especially for the disposal, manufacturing and use, and long-term storage in mines). The projected waste generation volumes and contaminant levels for each option were obtained from the engineering analysis report (LLNL 1997) and other programmatic sources for continued storage and long-term yard storage (Parks 1997; Folga 1996). The waste generation volumes projected for each site (or nationwide) are shown in Table C.3. To estimate waste, these projected site-dependent LLW and LLMW data were obtained from analysis of site-generated data listed in the *Integrated Data Base Report — 1994* (DOE 1995b) for LLW and from the *Mixed Waste Inventory Summary Report* (DOE 1995c) for LLMW. The estimated wastes generated from each depleted UF_6 management option are compared with the estimated waste treatment volumes listed in Table C.3. The treatment volumes in Table C.3 are associated with operations and do not include waste from environmental restoration activities.

Estimates of projected wastes for the next 20 years were used in this comparison rather than current waste volumes because the comparison should represent waste management conditions some 10 to 30 years from now. Waste management programs at particular sites could change over time.

Estimates of the LLW to be disposed of at DOE waste management disposal facilities depend critically upon the time frame under consideration and the types of waste to be included. The WM PEIS estimates that approximately 1,060,000 m^3 of LLW will be disposed of during the time frame 1995-2014 (DOE 1997). This estimate does not include any LLW from environmental restoration activities or facility stabilization activities. A more appropriate estimate that includes environmental restoration waste (perhaps more uncertain) comes from *The 1996 Baseline Environmental Management Report* (BEMR) (DOE 1996b), which estimates the total amount of LLW for treatment at waste management facilities to be 3,400,000 m^3. This estimate is for the next 75 years and includes contributions from environmental restoration and facility stabilization programs. The majority of environmental restoration wastes are expected to be generated between 2003 and 2033, approximately the correct time frame to compare with the depleted UF_6 program. For this reason, the BEMR estimate was used for comparison with the estimated depleted UF_6 waste. Adjustments must be made to the BEMR estimate to convert treatment volumes into disposal volumes. Both volume reductions and expansions would occur during waste treatment and grouting, depending on the relative amounts of the different types of waste. On the basis of the WM PEIS analysis (DOE 1997), the BEMR estimate was adjusted to 4,250,000 m^3 for the estimated disposal volume. The total disposal volumes for LLW generated from various depleted UF_6 alternatives were

TABLE C.3 Projected Site and National DOE Waste Treatment Volumes

	Waste Treatment Volume[a] (m^3/yr)			
Waste Category	Paducah	Portsmouth	K-25 (ORR)[b]	Nationwide
Low-level waste[c]	2,200	4,800	8,100	68,000[d]
Low-level mixed waste[e]	100	1,600	(5,000)	19,000[d]
Hazardous waste[f]	76	120	1,000	–
Nonhazardous waste[f]				
Solids	2,100	–	(27,500)	–
Wastewater	–	–	–	–
Sanitary waste	560,000	500,000	880,000	–

[a] A hyphen (–) indicates no data reported.

[b] Waste treatment volumes for the K-25 site are listed where available. Much of the waste generated at K-25 is included in the combined treatment volumes listed under the Oak Ridge Reservation (ORR) treatment, storage, and disposal facilities. These combined volumes (enclosed in parentheses) include waste generated at ORNL, K-25, and Y-12.

[c] Source: DOE (1995b).

[d] Estimated operational waste for 1995 for all DOE sources combined (DOE 1997).

[e] Source: DOE (1995c).

[f] Source: DOE (1995d).

compared to the total estimated disposal volume for LLW for all DOE waste management activities (including environmental restoration waste).

A distinction is made between treatment volumes and disposal volume. Treatment volumes were compared as cubic meters per year (m^3/yr) because the limitations to the treatment facility are likely related to the throughput volume (m^3/yr) of the treatment facility. Disposal volumes were compared as total cubic meters (m^3) because disposal facilities generally have no throughput limitations but rather are limited by the total volume of waste (m^3) they can accept.

Although the current LLW disposal capacity is inadequate to dispose of the projected 4 million m^3 of LLW, such land is available at DOE and commercial LLW disposal facilities to accommodate disposal of this waste (DOE 1992a). These lands will be developed for LLW disposal, as needed.

C.11 CULTURAL RESOURCES

Cultural resources were generally evaluated with respect to the potential for impact to archaeological sites and historic structures listed on or eligible for the *National Register of Historic Places*, the environmental setting of a listed or eligible property, and traditional use areas (e.g., cemetery, Native American resource). Because specific sites have not been chosen for the options (with the exception of continued storage and cylinder preparation activities), only limited impact evaluation was possible. A site-specific evaluation as a part of the second tier of NEPA documentation will assess the location of proposed ground disturbance with respect to locations of significant cultural resources to determine impacts.

For the continued storage and cylinder preparation options, information regarding cultural resources was collected from each of the three current storage sites (Paducah, Portsmouth, and K-25). The potential for impacts resulting from these options was determined on the basis of ground disturbance caused by the construction of the new storage yards (if any), or a new transfer facility. Although each of the sites will prepare its own NEPA documentation for these projects, this PEIS provides a general discussion of what potential impacts might occur.

C.12 RESOURCE REQUIREMENTS

The evaluation of resource requirements identified the major irreversible and irretrievable commitments of resources that could be determined at this programmatic level of analysis. The commitment of material and energy resources during the entire life cycle of the various options in this PEIS includes construction materials that could not be recovered or recycled, materials rendered radioactive that could not be decontaminated, and materials consumed or reduced to unrecoverable forms or waste. Where construction would be necessary, materials required could include wood, concrete, sand, gravel, steel, and other metals. Materials consumed during operations could include operating supplies, miscellaneous chemicals, and gases. Strategic and critical materials, or resources with small reserves, were also identified and considered.

Energy resources irretrievably committed during construction and operations would include the consumption of fossil fuels used to generate heat and electricity. Energy would also be expended in the form of diesel fuel, gasoline, and oil for construction equipment and transportation vehicles.

The assessment of potential resource requirements for the continued storage, cylinder preparation, conversion, and long-term storage options was based on comparing the resource requirements of building and operating proposed facilities to existing capacities of on-site infrastructure systems and to current off-site demands at the three current storage sites. A variation of the methodology applied in the WM PEIS (DOE 1997) was utilized in this study. The effects of the various options on on-site infrastructure systems such as electrical demand were assessed qualitatively by comparing the new demand to the existing maximum capacity. The demand on off-site infrastructure resulting from new resource requirements for each option was compared to estimated current demand.

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APPENDIX D:

ENVIRONMENTAL IMPACTS OF CONTINUED CYLINDER STORAGE AT CURRENT STORAGE SITES

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CONTENTS (Cont.)

TABLES

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TABLES (Cont.)

NOTATION (APPENDIX D)

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

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
K_d	distribution coefficient
LCF	latent cancer fatality
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
LMES	Lockheed Martin Energy Systems, Inc.
MCL	maximum contaminant level
MEI	maximally exposed individual
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 μm or less
ROI	region of influence
VOC	volatile organic compound

Chemicals

CO	carbon monoxide
HC	hydrocarbon
HF	hydrogen fluoride
NO_x	nitrogen oxides
SO_x	sulfur oxides
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2F_2	uranyl fluoride

UNITS OF MEASURE

ft	foot (feet)
ft^2	square foot (feet)
g	gram(s)
gal	gallon(s)
ha	hectare(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
µg	microgram(s)
µm	micrometer(s)
m	meter(s)
m^3	cubic meter(s)
mg	milligram(s)
min	minute(s)
mrem	millirem(s)
pCi	picocurie(s)
ppb	part(s) per billion
ppm	part(s) per million
rem	roentgen equivalent man
s	second(s)
yd^2	square yard(s)
yd^3	cubic yard(s)
yr	year(s)

APPENDIX D:

ENVIRONMENTAL IMPACTS OF CONTINUED CYLINDER STORAGE AT CURRENT STORAGE SITES

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

> **Continued Storage of Cylinders**
>
> The continued storage of depleted UF_6 cylinders at the Paducah, Portsmouth, and K-25 sites would be required for some period of time for all alternative management strategies. Continued storage would involve maintenance of the cylinders — including inspections, painting, and cylinder yard upgrades — as well as valve replacement and cylinder repair, as needed. The impacts of continued storage were assessed separately for the following:
>
> **No Action Alternative:** Potential impacts were assessed for continued storage of the entire cylinder inventory at the three current storage sites through the year 2039, including potential long-term impacts to groundwater and human health and safety.
>
> **Action Alternatives:** Potential impacts were assessed for continued storage at the three current storage sites based on the assumption that the number of cylinders at these sites would begin to decrease in the year 2009 and that all of the cylinders would be removed from the three sites by the end of the year 2028 (corresponding to the period during which conversion or long-term storage would be implemented). Potential long-term impacts were also assessed.

Continued cylinder storage at the Paducah, Portsmouth, and K-25 sites would be required for some period of time for all alternative management strategies. It was assumed that the entire depleted UF_6 cylinder inventory would continue to be stored at the three sites through 2008 for all alternatives. Under the no action alternative, the entire cylinder inventory would continue to be stored at the three sites indefinitely. For purposes of analysis and for comparison with action alternatives, the assessment period considered in this PEIS was through the year 2039. Under action alternatives, the number of cylinders stored at the three sites would decrease as the cylinders were transported to another location for conversion or long-term storage. This decrease at the sites was assumed to occur from 2009 through

2028.[1] The assessment of impacts from continued cylinder storage at the three sites considers all anticipated activities required to safely manage the cylinder inventory from 1999 through 2039 for the no action alternative and from 1999 through 2028 for the action alternatives. Potential long-term impacts from cylinder breaches potentially occurring at the sites through the year 2039 (No Action Alternative) or through 2028 (action alternatives) were estimated by calculating the maximum groundwater contamination levels possible in the future from those breaches.

The cylinder surveillance and maintenance activities that are to be undertaken from now through September 30, 2002, are described in detail in the *UF_6 Cylinder Project Management Plan* (Lockheed Martin Energy Systems [LMES] 1997d). However, because the assessment period for this PEIS extends through the year 2039, a set of assumptions was needed to define the activities for estimating the impacts of continued storage through 2039. The assumptions used are documented in a memo by J.W. Parks, Assistant Manager for Enrichment Facilities, DOE Oak Ridge Operations Office (Parks 1997). In developing these assumptions, it was recognized that the activities actually undertaken might differ from those described in the cylinder project management plan. Therefore, assumptions were chosen such that anticipated impacts of continued cylinder storage made in the PEIS would result in conservative estimates (that is, the assumptions used would overestimate impacts rather than underestimate them).

Impacts associated with the following activities were analyzed: (1) storage yard reconstruction and cylinder relocations; (2) routine and ultrasonic testing inspections of cylinders and valve monitoring and maintenance; (3) cylinder painting; and (4) repair and removal of the contents of any cylinders that might be breached during the storage period. Although actual activities occurring at the three storage sites during the time period considered might vary from those described in the cylinder project management plan, the estimated impacts of continued storage activities assessed in this PEIS are likely to encompass and bound the impacts at these sites. The assumptions for each activity are discussed further in the following paragraphs.

The total inventory of 46,422 depleted UF_6 cylinders generated by DOE before 1993 is currently stored as follows: 28,351 cylinders (about 60%) in 13 yards at the Paducah site; 13,388 cylinders (about 30%) in two yards at the Portsmouth site; and 4,683 cylinders (about 10%) in three yards at the K-25 site. An intensive effort is ongoing to improve yard storage conditions. This effort includes (1) relocation of some cylinders, which are currently either in contact with the ground or are too close to one another to allow for adequate inspections, and (2) construction of new storage yards or reconstruction of existing storage yards to provide a stabilized concrete base and monitored drainage for the cylinder storage areas. The impacts from planned relocation and construction activities that will not be complete by 1999 are included in the PEIS for consideration as part of continued cylinder storage; these activities include reconstruction of four Paducah yards, construction of a new yard for the K-25 site cylinders, relocation of about 19,000 cylinders at Paducah, and relocation of all cylinders at K-25.

---

[1] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

The stored cylinders are regularly inspected for evidence of damage or accelerated corrosion; about 75% are inspected every 4 years, and 25% are inspected annually. Annual inspections are required for those cylinders that have been stored previously in substandard conditions and/or those that show areas of heavy pitting or corrosion. In addition to these routine inspections, ultrasonic inspections are currently conducted on some of the relocated cylinders. The ultrasonic testing is a nondestructive method to measure the wall thickness of cylinders. Valve monitoring and maintenance are also conducted for cylinders that exhibit discoloration of the valve or surrounding area during routine inspections. Leaking valves are replaced in the field. Impacts from routine inspections, ultrasonic inspections, and valve maintenance are evaluated as components of continued cylinder storage. For assessment of the no action alternative, the frequency of routine inspections and valve monitoring was assumed to remain constant through 2039, and ultrasonic testing was assumed to be conducted annually for 10% of the relocated cylinders. Relocation activities would be completed in about 2003, after which 10% of the cylinders painted each year were assumed to be inspected by ultrasonic testing. For the action alternatives, the frequency of inspections was assumed to decrease with decreasing cylinder inventory (about a 5% decrease in inspections per year) from 2009 through 2028.

Current plans call for cylinder painting at the three sites to control cylinder corrosion. On the basis of information from the cylinder painting program (Pawel 1997), the analysis assumed that the paint would protect the cylinders for at least 10 years and that, once painted, the cylinders would not undergo further corrosion during that time. Although repainting might not actually be required every 10 years, the analysis assumed that every cylinder would be repainted every 10 years (except for the period 2019 through 2028 for the action alternatives, during which time no painting was assumed because of decreasing inventory size — i.e., cylinders being removed within 10 years for conversion or long-term storage elsewhere would not be repainted). The painting activity includes cylinder surface preparation (e.g., scraping and removal of rust deposits). Because some radioactive contaminants may exist on the surface of cylinders and because the metal content of the paints used previously are unknown, for purposes of the PEIS analysis the waste generated during surface preparation was considered to be low-level-mixed waste. Cylinder painting activities would be the primary source of potential radiological exposures for involved workers under the continued cylinder storage option.

Before 1998, seven breached cylinders had been identified at the three storage sites. Breached cylinders are cylinders that have a hole of any size at some location on the wall. Investigation of these breaches indicated that five of the seven were initiated by mechanical damage during stacking; the damage was not noticed immediately, and subsequent corrosion occurred at the damaged point. The other two cylinder breaches were concluded to have been caused by external corrosion due to prolonged ground contact. In 1998, one additional breached cylinder occurred during the course of cylinder maintenance operations. When cylinders are breached, moist air reacts with the exposed UF_6 and iron, resulting in the formation of a dense plug of uranium tetrafluoride (UF_4) and iron fluoride hydrates that prevents rapid loss of material from the cylinders. Further details on cylinder corrosion and releases due to breaches are given in Appendix B.

Considering the improved storage conditions in the yards, intensive inspection schedule, and the planned cylinder painting, the impact analysis for the no action alternative was based on the assumption that breaches resulting from corrosion would cease. Therefore, the primary potential cause of breaches considered for continued storage was mechanical damage occurring during cylinder handling (e.g., for painting or relocations). Although stringent inspection procedures are now in place to immediately identify and repair any cylinder breaches that might occur during handling, for purposes of analysis it was nonetheless assumed that breaches caused by mechanical damage would continue to occur at the same rate as in the past and that the breaches would go unidentified for a long enough time for releases to occur (see Appendix B). Using these assumptions, the total numbers of breaches assumed to occur from 1999 through 2039 for the no action alternative analyses (base case) were 36 for the Paducah site, 16 for the Portsmouth site, and 7 for the K-25 site.

The above breach numbers were used to estimate potential impacts from repairing breached cylinders and from releases that might occur during continued storage through 2039 under the no action alternative. Potential radiological exposures of involved workers could result from patching breached cylinders and subsequently emptying the cylinder contents into new cylinders. The impacts to groundwater and human health and safety from uranium releases were assessed by estimating the amount of uranium that could be transported from the yards in surface runoff, followed by estimating migration through the soil to the groundwater.

The uncertainty in both the effectiveness of painting in controlling further corrosion and in the future painting schedule was addressed by also conducting a conservative assessment based on the assumption that external corrosion was not halted by improved storage conditions and painting, resulting in more breaches (see Section D.3). Using these assumptions, the total numbers of breaches estimated from 1999 through 2039 were 444 for the Paducah site, 74 for the Portsmouth site, and 213 for the K-25 site. The results of this assessment were used to provide an estimate of the earliest time when continued cylinder storage could begin to raise regulatory concerns under these worst-case conditions.

For the action alternatives, continued storage at the three sites would occur through 2028, with the inventory decreasing by about 5% per year starting in 2009 until no cylinders would remain at the current sites in 2028. Because the status of a cylinder painting program is less certain for the action alternatives, the estimated number of breached cylinders for these alternatives was based on the assumption that external corrosion was not controlled by painting (see Appendix B for the specific number of breaches assumed and Section D.4 for discussion of potential impacts for the action alternatives).

For all hypothetical cylinder breaches, it was assumed that the breach would go undetected for a period of 4 years, which is the duration between planned inspections for most of the cylinders. In practice, cylinders that show evidence of damage or heavy external corrosion are inspected annually, so it is unlikely that a breach would go undetected for a 4-year period. On the basis of estimates from investigation of cylinder breaches that have occurred to date, 1 lb (0.45 kg) of uranium (in the form of uranyl fluoride [UO_2F_2]) and 4.4 lb (2 kg) of hydrogen fluoride (HF) were assumed to be released from each breached cylinder annually for a period of 4 years.

D.1 SUMMARY OF CONTINUED CYLINDER STORAGE IMPACTS

This section provides a summary of the potential environmental impacts associated with continued cylinder storage at the three current storage sites for the no action alternative and for the other alternatives. Additional discussion and details related to the assessment methodologies and results for each area of impact are provided in Sections D.2 and D.4. The potential environmental impacts of continued cylinder storage are summarized in Table D.1 and as follows:

- Through the year 2039 for the no action alternative and the year 2028 for the action alternatives, all health and safety impacts to workers and the general public in the vicinity of the sites as a result of cylinder storage and maintenance activities are estimated to be well within the applicable health and safety standards.

- All postulated accidents, including the highest consequence accidents, were estimated to result in zero latent cancer fatalities (LCFs) due to radiological causes among both workers and members of the general public. Some accidents, if they occurred, could result in up to 300 irreversible adverse effects among workers and 1 irreversible adverse effect among the general public due to chemical effects of released materials. However, such accidents have a very low probability and would not be expected to occur through the year 2039 for the no action alternative and the year 2028 for the action alternatives.

- During the assessment period (through 2039 under the no action alternative and 2028 under the action alternatives), all environmental impacts resulting from continued storage activities, including impacts to air resources, water resources, socioeconomics, ecological resources, waste management, land and other resources, cultural resources, and the environmental justice impacts would be negligibly small or well within the applicable standards.

- Long-term impacts from cylinder breaches estimated to occur through 2039 under the no action alternative would be well within the applicable standards assuming that cylinder painting would be effective in controlling corrosion. If no credit were taken for corrosion reduction through painting and continued maintenance, and on the basis of conservative estimates of numbers of breaches and material loss from breached cylinders, it is estimated that the uranium concentrations in the groundwater around the three sites would exceed the guideline of 20 μg/L used for comparison at some time in the future (around the year 2100 or later). Similarly, if the larger number of cylinder breaches occurred because of uncontrolled cylinder corrosion, air concentrations of HF at the K-25 site could exceed the State of Tennessee standard around the year 2020. For the action alternatives, all long-term impacts are estimated to remain within the guideline values with or without taking credit for reduced corrosion through painting.

TABLE D.1 Summary of Continued Cylinder Storage Impacts[a]

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Human Health – Normal Operations: Radiological			
Involved Workers: Total collective dose (3 sites): 1,500 person-rem	**Involved Workers:** No impacts	**Involved Workers:** Total collective dose (3 sites): 720 person-rem	**Involved Workers:** No impacts
Total number of LCFs (3 sites): 0.6 LCF		Total number of LCFs (3 sites): 0.3 LCF	
Noninvolved Workers: Maximum annual dose to MEI: 0.043 – 0.11 mrem/yr	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** Maximum annual dose to MEI: 0.057 – 0.26 mrem/yr	**Noninvolved Workers:** No impacts
Maximum annual cancer risk to MEI: $2 \times 10^{-8} - 4 \times 10^{-8}$ per year		Maximum annual cancer risk to MEI: $2 \times 10^{-8} - 1 \times 10^{-7}$ per year	
Total collective dose (3 sites): 0.12 person-rem		Total collective dose (3 sites): 0.47 person-rem	
Total number of LCFs (3 sites): 5×10^{-5} LCF		Total number of LCFs (3 sites): 0.0002 LCF	
General Public: Maximum annual dose to MEI: 0.02 – 0.16 mrem/yr	**General Public:** Maximum annual dose to MEI: 0.026 – 0.49 mrem/yr	**General Public:** Maximum annual dose to MEI: 0.022 – 0.46 mrem/yr	**General Public:** Maximum annual dose to MEI: 0.021 – 1.3 mrem/yr
Maximum annual cancer risk to MEI: $1 \times 10^{-8} - 8 \times 10^{-8}$ per year	Maximum annual cancer risk to MEI: $1 \times 10^{-8} - 2 \times 10^{-7}$ per year	Maximum annual cancer risk to MEI: $1 \times 10^{-8} - 2 \times 10^{-7}$ per year	Maximum annual cancer risk to MEI: $1 \times 10^{-8} - 7 \times 10^{-7}$ per year
Total collective dose to population within 50 miles (3 sites): 0.38 person-rem	Total collective dose to population within 50 miles (3 sites): not determined	Total collective dose to population within 50 miles (3 sites): 1.07 person-rem	Total collective dose to population within 50 miles (3 sites): not determined
Total number of LCFs in population within 50 miles (3 sites): 2×10^{-4} LCF	Total number of LCFs in population within 50 miles (3 sites): not determined	Total number of LCFs in population within 50 miles (3 sites): 0.0005 LCF	Total number of LCFs in population within 50 miles (3 sites): not determined

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Human Health – Normal Operations: Chemical			
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts	**General Public:** No impacts
Human Health – Accidents: Radiological			
Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents	Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 8×10^{-6} per year Collective dose: 16 person-rem Number of LCFs: 6×10^{-3}		**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 8×10^{-6} per year Collective dose: 16 person-rem Number of LCFs: 6×10^{-3}	
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 1×10^{-5} per year Collective dose to population within 50 miles: 63 person-rem Number of LCFs in population within 50 miles: 3×10^{-2}		**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 1×10^{-5} per year Collective dose to population within 50 miles: 63 person-rem Number of LCFs in population within 50 miles: 3×10^{-2}	

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Human Health – Accidents: Chemical			
Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents	Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents
Noninvolved Workers: Bounding accident consequences (per occurrence):		**Noninvolved Workers:** Bounding accident consequences (per occurrence):	
Number of persons with potential for adverse effects: 1,000 persons		Number of persons with potential for adverse effects: 1,000 persons	
Number of persons with potential for irreversible adverse effects: 300 persons		Number of persons with potential for irreversible adverse effects: 300 persons	
General Public: Bounding accident consequences (per occurrence):		**General Public:** Bounding accident consequences (per occurrence):	
Number of persons with potential for adverse effects: 1,900 persons		Number of persons with potential for adverse effects: 1,900 persons	
Number of persons with potential for irreversible adverse effects: 1 person		Number of persons with potential for irreversible adverse effects: 1 person	
Human Health — Accidents: Physical Hazards			
Construction and Operations: **All Workers:** Less than 1 (0.11) fatality, approximately 143 injuries	No activities in the long term	**Construction and Operations:** **All Workers:** Less than 1 (0.07) fatality, approximately 90 injuries	No activities in the long term

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
		Air Quality	
Construction: 24-hour PM_{10} potentially as large as 82% of standard and 96% of standard at the Paducah and K-25 sites, respectively. Concentrations of other pollutants all below 3% of respective standards. No construction at the Portsmouth site. **Operations:** 24-hour HF impact potentially as large as 23% of standard at the K-25 site. Criteria pollutant impacts all below 0.3% of respective standards.	No activities in the long term	**Construction:** 24-hour PM_{10} potentially as large as 82% of standard and 96% of standard at the Paducah and K-25 sites, respectively. Concentrations of other pollutants all below 3% of respective standards. No construction at the Portsmouth site. **Operations:** 24-hour HF impact potentially as large as 92% of standard at the K-25 site. Criteria pollutant impacts all below 0.1% of respective standards.	No activities in the long term
		Water	
Construction: Negligible impacts **Operations:** Negligible impacts to surface water and groundwater	Negligible impacts to surface water and groundwater in the long term	**Construction:** No impacts **Operations:** Negligible impacts to surface water; negligible to minor impacts to groundwater	Negligible impacts to surface water and groundwater in the long term
		Soil	
Construction: Minor, but temporary, impacts **Operations:** Negligible impacts	No activities in the long term	**Construction:** No impacts **Operations:** Negligible impacts	No activities in the long term

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
		Socioeconomics	
Construction and Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public housing	No activities in the long term	**Construction and Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public housing	No activities in the long term
		Ecology	
Construction: Negligible impacts **Operations:** Negligible impacts to vegetation and wildlife	Negligible impacts to vegetation and wildlife in the long term	**Construction:** Negligible impacts **Operations:** Negligible impacts to vegetation and wildlife	Negligible to low impacts to vegetation and wildlife in the long term
		Waste Management	
Negligible impacts for the Portsmouth and K-25 sites; moderate impacts for the Paducah site waste management operations; negligible impacts to regional or national waste management operations for all three sites	No activities in the long term	Negligible impacts for the Portsmouth and K-25 sites; moderate impacts for the Paducah site waste management operations; negligible impacts to regional or national waste management operations for all three sites	No activities in the long term
		Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No activities in the long term	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No activities in the long term
		Land Use	
Negligible impacts	No activities in the long term	Negligible impacts	No activities in the long term

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
		Cultural Resources	
No impacts at the Paducah and Portsmouth sites. Impacts cannot be determined at K-25 for construction	No activities in the long term	No impacts at the Paducah and Portsmouth sites. Impacts cannot be determined at K-25 for construction	No activities in the long term
		Environmental Justice	
No disproportionate impacts	No activities in the long term	No disproportionate impacts	No activities in the long term

[a] Under the no action alternative, continued storage of the entire cylinder inventory would take place at the three sites; under the action alternatives, the number of cylinders stored at the three sites would decrease by 5% annually from 2009 through 2028.

Under all alternatives, potential long-term impacts were evaluated for uranium contamination of soil and groundwater from cylinder breaches through 2028 or 2039.

[b] The bounding radiological accident was defined as the accident that would result in the highest dose and risk to the general public MEI; the bounding chemical accident was defined as the accident that would result in the highest population risk (number of people affected).

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

D.2 POTENTIAL IMPACTS OF CONTINUED CYLINDER STORAGE FOR THE NO ACTION ALTERNATIVE

The potential environmental impacts from continued cylinder storage for the no action alternative were evaluated on the basis of activities that were assumed to be required to ensure safe storage of the cylinders (Parks 1997). These activities include routine and ultrasonic inspections of cylinders, valve maintenance, cylinder painting, storage yard reconstruction, and cylinder relocations. Although these activities would minimize the occurrence of cylinder breaches and would aid in the early identification of breached cylinders, the impacts associated with cylinder breaches that might occur during continued storage were assessed. The assessment methodologies are described in Appendix C.

Assumptions for continued storage were generally selected in a manner intended to produce conservative estimates of impact, that is, the assumptions result in an overestimate of the expected impact. Therefore, although actual activities occurring at the three storage sites during the time period considered might vary, the estimated impacts of continued storage activities assessed in this PEIS are likely to encompass and bound the impacts that could occur at these sites. The following general assumptions apply to continued cylinder storage for the no action alternative:

- The current inventories of cylinders at the three sites would be maintained at the sites through the year 2039.

- The number of breaches assumed to occur under the no action alternative accounts for continued external corrosion prior to the completion of painting of the cylinder inventory. After painting, external corrosion was assumed to cease. Estimated numbers of breaches initiated by mechanical damage caused during cylinder handling are also included. Although current maintenance procedures would most likely lead to immediate identification and repair of any cylinder breaches, some releases of uranium and HF from breached cylinders were assumed for assessment purposes. Impacts were assessed for workers handling the breached cylinders, as well as for noninvolved workers and members of the general public exposed to materials released from breached cylinders.

- To assess potential long-term impacts to groundwater and human health and safety from breached cylinders, potential future groundwater contamination was assessed by assuming that released uranium would be transported from the cylinder storage yards in surface runoff and then migrate through the soil and into groundwater. It was further assumed that public access would be possible for groundwater at the location of the nearest discharge point (i.e., the nearest surface water body in the direction of groundwater flow).

- To address uncertainty in corrosion and cylinder breach assumptions, an assessment was also conducted assuming that external corrosion was not halted by improved maintenance conditions (see Section D.3 for a discussion of potential impacts).

D.2.1 Human Health — Normal Operations

D.2.1.1 Radiological Impacts

Radiological impacts from normal operations of the cylinder storage yards were assessed for the involved workers, noninvolved workers, and off-site general public. Radiation exposures of involved workers would result primarily from external radiation from inspecting and handling the cylinders. Exposures of noninvolved workers would result from airborne releases of uranyl fluoride (UO_2F_2) from breached cylinders. In addition to exposures from airborne releases of UO_2F_2, the analysis also considered potential exposures of the off-site public to waterborne releases of UO_2F_2. Such releases would be possible if UO_2F_2 was deposited on the ground surface and washed off by rain to a surface water body or infiltrated with rain to the deeper soil, thereby reaching the groundwater underlying the storage yards. Detailed discussions of the methodologies used in radiological impact analyses are provided in Appendix C and Cheng et al. (1997).

The estimated radiation doses and latent cancer risks for each of the three storage sites are provided in Tables D.2 and D.3, respectively. During the storage periods, average radiation exposures of involved workers would be less than 750 mrem/yr; exposures of noninvolved workers and members of the general public would be less than 1 mrem/yr. The long-term effects of radiation exposure on the general public resulting from groundwater contamination would be less than 2 mrem/yr. Potential long-term radiological impacts (based on groundwater contamination) are provided in Table D.4.

D.2.1.1.1 Paducah Site

The average annual collective worker dose for continued storage activities at the Paducah site would be about 22 person-rem/yr for about 30 workers for the period from 1999 through 2039. The number of workers required for this period was estimated on the basis of the anticipated activities (Parks 1997) and the assumption that the workers would work 5 hours per day in the storage yard. The average individual worker dose would vary from year to year and was estimated to average 740 mrem/yr, which is considerably below the regulatory limit of 5,000 mrem/yr (*10 Code of Federal Regulations* [CFR] Part 835) and also below the DOE administrative control limit of 2,000 mrem/yr (DOE 1992). Compared with the historical data for worker exposure of 16 to 56 mrem/yr (Hodges 1996), the estimated exposures are greater because of the conservative

TABLE D.2 Radiological Doses from Continued Cylinder Storage under Normal Operations for the No Action Alternative

	Annual Dose to Receptor					
	Involved Workers[a]		Noninvolved Workers[b]		General Public	
Site	Average Individual Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[c] (mrem/yr)	Collective Dose[d] (person-rem/yr)	MEI Dose[e] (mrem/yr)	Collective Dose[f] (person-rem/yr)
Paducah	740	22	0.11	0.0023	0.013 (< 0.017)	0.0053
Portsmouth	600	9.2	0.043	0.00031	0.012 (< 0.0077)	0.0013
K-25	410	4.9	0.048	0.00021	0.11 (< 0.051)	0.0026

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual dose and collective dose for the worker population. The reported values are averages over the time period 1999-2039. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[b] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

[c] The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest dose. The reported values are the maximums over the time period considered.

[d] The reported collective doses are averages over the time periods considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

[e] The MEI for the general public was assumed to be located off-site at a point that would yield the largest dose. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[f] Collective dose was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.3 Latent Cancer Risks from Continued Cylinder Storage under Normal Operations for the No Action Alternative

	Annual Risk of Latent Cancer Fatality to Receptor					
	Involved Worker[a]		Noninvolved Worker[b]		General Public	
Site	Average Individual Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[c] (risk/yr)	Collective Risk[d] (fatalities/yr)	MEI Risk[e] (risk/yr)	Collective Risk[f] (fatalities/yr)
Paducah	3×10^{-4}	9×10^{-3}	4×10^{-8}	9×10^{-7}	6×10^{-9} ($< 2 \times 10^{-9}$)	3×10^{-6}
Portsmouth	2×10^{-4}	4×10^{-3}	2×10^{-8}	1×10^{-7}	6×10^{-9} ($< 8 \times 10^{-10}$)	6×10^{-7}
K-25	2×10^{-4}	2×10^{-3}	2×10^{-8}	8×10^{-8}	5×10^{-8} ($< 5 \times 10^{-9}$)	1×10^{-6}

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual risk and collective risk for the worker population. The reported values are averages over the time period 1999-2039.

[b] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

[c] The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest risk. The reported values are the maximums over the time period considered.

[d] The reported collective risks are averages over the time period considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

[e] The MEI for the general public was assumed to be located off-site at a point that would yield the largest risk. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[f] Collective risk was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.4 Long-Term Radiological Impacts to Human Health from Continued Cylinder Storage under the No Action Alternative[a,b]

	Impact to MEI of General Public	
Storage Location	Radiation Dose[c] (mrem/yr)	Latent Cancer Risk[c] (risk/yr)
Paducah site	0.051 – 0.41	$3 \times 10^{-8} - 2 \times 10^{-7}$
Portsmouth site	0.026 – 0.33	$1 \times 10^{-8} - 2 \times 10^{-7}$
K-25 site	0.051 - 0.49	$3 \times 10^{-8} - 2 \times 10^{-7}$

[a] The long-term impacts correspond to the time after the year 2039.

[b] Long-term impacts would be caused by the potential use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. Contamination of groundwater would result from releases from hypothetically breached cylinders and the resulting infiltration of UO_2F_2 to the deeper soils, eventually reaching the groundwater (UO_2F_2 is the product of UF_6 reacting with moisture in air).

[c] Radiation doses and latent cancer risks are expressed as ranges, which would result from different transport speeds of uranium in soil. The reported values are the maximum values that would occur after 2039, assuming no mitigation action was taken.

assumptions made regarding future inspection and maintenance activities (Parks 1997) and the conservatism applied in the analytical methods (see Appendix C, Section C.4.1).

Radiation doses to noninvolved workers who worked on-site but not within the cylinder storage yards would be less than 0.11 mrem/yr, primarily from inhalation of UO_2F_2 released from breached cylinders. Radiation exposures of members of the off-site general public would result from both airborne and waterborne releases of UO_2F_2. The radiation dose to the maximally exposed individual (MEI) would be less than 0.03 mrem/yr (0.013 mrem/yr from exposure to airborne releases and 0.017 mrem/yr from using contaminated groundwater). The radiation dose from drinking contaminated surface water would be less than 2×10^{-7} mrem/yr. The dose of 0.03 mrem/yr is considerably below the regulatory limit of 10 mrem/yr (40 CFR Part 61) from airborne emissions and 100 mrem/yr (DOE Order 5400.5) from all exposure pathways. The exposure to the off-site public from continued storage activities would be very small compared with the existing exposures (about 3.03 mrem/yr) (LMES 1996a) from operations of the entire Paducah site.

Potential exposures to members of the off-site public after the year 2039 were also assessed for the use of contaminated groundwater resulting from breaches occurring prior to 2039. Depending on the soil properties that determine the time it takes the uranium to reach the groundwater, the maximum individual dose could range from 0.051 to 0.41 mrem/yr, which is considerably lower than the regulatory limit of 100 mrem/yr.

D.2.1.1.2 Portsmouth Site

In general, the estimated radiation doses from continued storage activities at the Portsmouth site would be less than those for the Paducah site because a smaller number of cylinders would be managed at Portsmouth. The average annual collective worker dose would be 9.2 person-rem/yr for about 16 workers for the period from 1999 through 2039. The average individual worker dose would be about 600 mrem/yr for this operational period, which is below the regulatory limit of 5,000 mrem/yr and the DOE administrative control limit of 2,000 mrem/yr. The estimated average worker dose is greater than the historical data of 55 to 196 mrem/yr (Hodges 1996) because of the more vigorous inspection and maintenance activities planned to be implemented. The radiation dose to noninvolved workers from airborne release of UO_2F_2 would be less than 0.043 mrem/yr for all periods.

The radiation dose to the maximally exposed member of the public would be less than 0.02 mrem/yr (0.012 mrem/yr from airborne releases plus 0.0077 mrem/yr from using contaminated groundwater), considerably below the regulatory limit of 10 mrem/yr from airborne emissions and 100 mrem/yr from all exposure pathways. The radiation dose from drinking contaminated surface water would be 2.1×10^{-5} mrem/yr. Compared with the existing exposure from operations for the entire Portsmouth site (0.066 mrem/yr; LMES 1996b), the dose to the MEI from continued storage activities would be smaller. The long-term radiological impacts to the general public from using contaminated groundwater would range from 0.026 to 0.33 mrem/yr — depending on the soil properties, which would determine the time it took for the uranium to reach the groundwater.

D.2.1.1.3 K-25 Site

The estimated radiation doses to involved workers from continued storage activities at the K-25 site would be less than those for the Paducah and Portsmouth sites because the smallest number of cylinders would be managed at K-25. The average annual collective worker dose would be about 4.9 person-rem/yr for approximately 13 workers for the period from 1999 through 2039. The average individual dose would be about 410 mrem/yr for this period, considerably below the regulatory limit of 5,000 mrem/yr and the DOE administrative control limit of 2,000 mrem/yr. Exposure of involved workers would be greater than the historical data of 32 to 92 mrem/yr (Hodges 1996) because of more worker activities planned to be implemented. Radiation exposure of noninvolved workers at the K-25 site would be less than 0.048 mrem/yr from airborne release of UO_2F_2.

The radiation dose to the MEI of the off-site public resulting from breached cylinders at the K-25 site would be greater than the doses at the Paducah and Portsmouth sites because of the shorter distance assumed between the emission point and the site boundary. As a result, the estimated radiation dose to the MEI of the general public would also be greater than the dose to noninvolved workers. Potential exposure of the general public MEI would be less than 0.16 mrem/yr (0.11 mrem/yr from exposure to airborne releases and 0.051 mrem/yr from using contaminated groundwater). The radiation dose from drinking contaminated surface water would be less than 0.000011 mrem/yr. The radiation dose of 0.16 mrem/yr would be less than the existing exposure of approximately 5 mrem/yr from operation of the entire Oak Ridge Reservation (LMES 1995). The long-term radiological impacts to the general public from using contaminated groundwater would range from 0.051 to 0.49 mrem/yr, which is very low compared with the dose limit of 100 mrem/yr from all exposure pathways.

D.2.1.2 Chemical Impacts

Chemical impacts during continued cylinder storage could result primarily from exposure to UO_2F_2 (the product formed when UF_6 is exposed to moist air) and HF released from hypothetical cylinder breaches. Risks from normal operations were quantified on the basis of calculated hazard indexes. Detailed discussions of the exposure assumptions, health effects assumptions, reference doses used for uranium compounds and HF, and calculational methods used in the chemical impact analysis are provided in Appendix C and Cheng et al. (1997).

Hazardous chemical impacts to the MEI at the three current storage yards were calculated for both noninvolved workers and members of the general public; the results are summarized in Table D.5. Chemical exposures of noninvolved workers and the off-site general public could result from airborne emissions of UO_2F_2 and HF that could be dispersed from hypothetical cylinder breaches into the atmosphere and to the ground surface. The exposure pathways assessed included inhalation of UO_2F_2 and HF and ingestion of UO_2F_2 in soil. In all cases, the MEI hazard index would be considerably below 1, indicating no potential adverse health effects.

D.2.2 Human Health — Accident Conditions

A range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents was presented in the safety analysis reports (SARs) for the three storage sites (LMES 1997a–c). The potential accidents discussed in the SARs included natural phenomena events such as earthquakes, tornadoes, and floods, and spills from corroded cylinders under various weather conditions. The accidents selected for PEIS analyses were those accident scenarios in the SARs that resulted in the greatest potential consequences at each of the three storage sites for each of the four frequency categories (likely, unlikely, extremely unlikely, and incredible); these accidents are listed in Table D.6. The accidents selected for the PEIS analyses and

TABLE D.5 Chemical Impacts to Human Health from Continued Cylinder Storage under Normal Operations for the No Action Alternative

	Impacts to Receptor			
	Noninvolved Workers[a]		General Public[b]	
Site/Time Period	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)
Paducah site				
1999-2039	1.0×10^{-3}	–	2.6×10^{-3} ($\leq 2.1 \times 10^{-3}$)	–
Long-term impacts[e]	NA[f]	–	0.01 – 0.05	–
Portsmouth site				
1999-2039	4.4×10^{-5}	–	2.6×10^{-3} ($\leq 9.7 \times 10^{-4}$)	–
Long-term impacts[e]	NA	–	0.003 – 0.04	–
K-25 site				
1999-2039	4.8×10^{-4}	–	2.3×10^{-2} ($\leq 6.4 \times 10^{-3}$)	–
Long-term impacts[e]	NA	–	0.01 – 0.06	–

[a] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. The MEI for the noninvolved worker was assumed to be at the on-site (outside storage yards) location that would yield the largest exposure. Exposures would result from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders; the exposure pathways considered included inhalation and incidental ingestion of soil.

[b] The MEI for the general public was assumed to be located off-site at the point that would yield the largest exposure. Results reported are the maximum values over the time period considered and would result from exposure via inhalation; ingestion of soil (resulting from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders); and drinking surface water (consequence of the discharge of contaminated runoff water to a surface water body). Potential impacts during the storage period 1999-2039 (values within parentheses) were also evaluated from the use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

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

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

[e] Long-term impacts would result from using contaminated groundwater. Ranges result from different transport speeds of uranium in soil. The reported values are the maximum values that would occur after 2039, assuming no mitigative measures were taken.

[f] NA = not applicable; workers were assumed not to ingest groundwater.

TABLE D.6 Accidents Considered for the Continued Storage Option

Site/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Paducah Site					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in. deep water pool.	HF	150	60 (continuous)	Ground
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Vehicle-induced fire, 3 full 48Y cylinders	Three full 48Y UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 18,000 2,770 8,010	0 to 24 24 24 to 30 30 to 236	Ground
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Small plane crash, 2 full 48Y cylinders	A small plane crash affects two full 48Y UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 6,020 920 2,670	0 to 24 24 24 to 30 30 to 236	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	3,210 2,730	0 to 30 30 to 236	Ground

TABLE D.6 (Cont.)

Site/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Portsmouth Site					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in. deep water pool.	HF	150	60 (continuous)	Ground
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Vehicle-induced fire, 3 full 48Y cylinders	Three full 48Y UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 18,000 2,770 8,010	0 to 24 24 24 to 30 30 to 236	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Small plane crash, 2 full 48Y cylinders	A small plane crash affects two full 48Y UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 6,020 920 2,670	0 to 24 24 24 to 30 30 to 236	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	3,210 2,730	0 to 30 30 to 236	Ground

TABLE D.6 (Cont.)

Site/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
K-25 Site					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground

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

listed in Table D.6 do not include natural phenomena events, which were found in the SARs to have less serious consequences than other types of accident scenarios (e.g., a vehicle-induced fire affecting three UF_6 cylinders). In those instances where it was not absolutely clear from the SAR which accident would be the bounding accident in a frequency category at a site, several accidents were included in the PEIS analyses, as indicated in Table D.6. The resulting radiological doses and adverse health impacts from chemical exposures for all the accidents listed in Table D.6 are presented in Policastro et al. (1997). In the following sections, the results for only the bounding accident in each frequency category at each site are presented. Detailed descriptions of the methodology and assumptions used in these calculations are provided in Appendix C and Policastro et al. (1997).

D.2.2.1 Radiological Impacts

Table D.7 lists the radiological doses to various receptors for the accidents that give the highest dose from each frequency category. The LCF risks for these accidents are given in Table D.8. The doses and the risks are presented for two different meteorological conditions (D and F stability classes) at the three current storage sites (see Appendix C). The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely (EU) category have a probability of occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. The following conclusions may be drawn from the radiological health impact results:

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

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

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

D.2.2.2 Chemical Impacts

The accidents discussed in this section are listed in Table D.6. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables D.9 and D.10. The results are presented as (1) number of persons with the potential for adverse effects and (2) number of persons 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 workers and off-site population) (Policastro et al. 1997). The impacts presented are based on the assumption that the accidents would occur. The accidents listed in Tables D.9 and D.10 are not identical because an accident with the largest impacts for the adverse effects endpoint might not lead to the largest impacts for the irreversible adverse effects endpoint. Detailed descriptions of the

TABLE D.7 Estimated Radiological Doses per Accident Occurrence for Continued Cylinder Storage under the No Action Alternative

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

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

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

[c] Maximum and minimum doses reflect differences in assumed meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed. An exception is the vehicle-induced fire involving 3 full 48G cylinders, which would result in a higher population dose for the general public under D stability with 4 m/s wind speed.

TABLE D.8 Estimated Radiological Health Risks per Accident Occurrence for Continued Cylinder Storage under the No Action Alternative[a]

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

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCF) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; 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); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum risks reflect differences in assumed meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed. An exception is the vehicle-induced fire involving 3 full 48G cylinders, which would result in a higher population dose for the general public under D stability with 4 m/s wind speed.

TABLE D.9 Number of Persons with Potential for Adverse Effects from Accidents under Continued Cylinder Storage for the No Action Alternative[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Paducah									
Corroded cylinder spill, dry conditions	L	Yes	10	No	0	Yes	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	690	Yes	14	Yes	7	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	910	Yes	1,900	Yes	4	Yes	3
Portsmouth									
Corroded cylinder spill, dry conditions	L	Yes	48	Yes[f]	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	850	Yes	12	Yes	2	Yes[f]	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	1,000	Yes	650	Yes	160	Yes	4
Small plane crash, 2 full 48Y cylinders	I	Yes	760	Yes	6	No	0	No	0
K-25									
Corroded cylinder spill, dry conditions	L	Yes	69	No	0	Yes[f]	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	700	Yes	18	Yes	47	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	770	Yes	550	No	0	Yes	12
Small plane crash, 2 full 48G cylinders	I	Yes	420	Yes	34	No	0	No	0

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

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

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

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

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

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

TABLE D.10 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under Continued Cylinder Storage for the No Action Alternative[a]

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

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

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site 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 the meteorological condition of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

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

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

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

methodology and assumptions for assessing chemical impacts are provided in Appendix C). The following conclusions may be drawn from the chemical impact results:

- If the accidents identified in Tables D.9 and D.10 did occur, the number of persons in the off-site population with the potential for adverse effects would range from 0 to 1,900 (maximum corresponding to the vehicle-induced fire scenario at the Paducah site), and the number of off-site persons with potential for irreversible adverse effects would range from 0 to 7 (maximum corresponding to the corroded cylinder spill with pooling conditions scenario at the Portsmouth site).

- If the accidents identified in Tables D.9 and D.10 did occur, the number of noninvolved workers with the potential for adverse effects would range from 0 to 1,000 (maximum corresponding to the vehicle-induced fire scenario at the Portsmouth site), and the number of noninvolved workers with the potential for irreversible adverse effects would range from 0 to 300 (maximum corresponding to the corroded cylinder spill with pooling scenario at the Paducah site).

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

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (41 years, 1999-2039). The results indicate that the maximum risk values would be less than 1 for all accidents, except the following:

  - *Potential Adverse Effects:*

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

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

  - *Potential Irreversible Adverse Effects:*

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

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

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

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated potential irreversible adverse effects was estimated. All the bounding case accidents shown in Table D.10 would involve releases of UF_6 and potential exposure to HF and uranium compounds. These exposures would likely be high enough to result in death for 1% or less of the persons experiencing irreversible adverse effects (Policastro et al. 1997). This would mean that for workers experiencing a range of 0 to 300 irreversible adverse effects, approximately 0 to 3 deaths would be expected. Similarly, of the general public experiencing a range of 0 to 1 irreversible adverse effects, less than 1 death would be expected. These are the maximum potential consequences of the accidents, the upper ends of the ranges assume worst-case weather conditions and that the wind would be blowing in the direction where the highest number of people would be exposed.

D.2.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries for workers (involved and noninvolved) conducting activities associated with continued storage was calculated using industry-specific statistics from the U.S. Bureau of Labor Statistics, as reported by the National Safety Council (1995). Annual fatality and injury rates for manufacturing activities were used for all activities except cylinder yard construction or reconstruction; rates specific to construction were available for these activities. Injury incidence rates used were for injuries involving lost workdays (not including the day of injury). No on-the-job fatalities and less than 100 injuries would be expected during the entire continued cylinder storage period.

The activities included as part of the continued storage strategy are routine cylinder inspections, ultrasonic inspections, valve monitoring and maintenance activities, cylinder relocations, cylinder yard construction or reconstruction, cylinder painting, and patching and content transfers for breached cylinders (Parks 1997). These activities were assumed to be continued at currently planned levels through the year 2039, except for yard construction and reconstruction, which were assumed to be completed by the year 2003. The annual labor requirements and the corresponding fatality and injury risks for these activities were estimated to be as follows: the total three-site fatality risk would be less than 1 (0.11), and the total three-site injury risk would be about 140 injuries (see Table D.11).

TABLE D.11 Estimated Impacts to Human Health from Physical Hazards under Continued Cylinder Storage for the No Action Alternative[a,b]

Impacts to All Workers (Involved and Noninvolved)[c]							
Fatality Incidence				Injury Incidence			
Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites	Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites
0.056	0.030	0.026	0.11	71	39	33	143

[a] Potential impacts are based on continued storage activities, which would include routine inspections, ultrasonic inspections, valve monitoring and maintenance, cylinder relocations, cylinder yard construction and reconstruction, cylinder painting, and patching and content transfers for breached cylinders for the time period 1999-2039.

[b] Risk estimates include reconstruction of L-, M-, N-, and P-yards at Paducah and construction of a new yard at K-25.

[c] Injury and fatality incidence rates used in the calculations were taken from National Safety Council (1995).

D.2.3 Air Quality

The analysis of air quality impacts for continued cylinder storage under the no action alternative was based on three emissions-producing activities: (1) construction of new storage yards; (2) relocation and painting of cylinders; and (3) estimated HF emissions resulting from hypothetical cylinder breaches. The air quality impacts of these three activities are addressed by site in Sections D.2.3.1 through D.2.3.3. Additional details on the assessment of air quality impacts is presented in Tschanz (1997a-b).

D.2.3.1 Paducah Site

The potential impacts of construction were modeled on the basis of assuming area sources located at the yards being reconstructed. The maximum impacts at the Paducah site would occur in 1999 when the L-yard is scheduled for reconstruction. The 1-hour and annual maximum concentrations of criteria pollutants — hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM_{10}) — that would occur during construction of that yard are listed in Table D.12. The annual PM_{10} concentration of 16.7 $\mu g/m^3$ is about 33% of the applicable 50 $\mu g/m^3$ standard. The 24-hour estimated maximum PM_{10} concentration of 131 $\mu g/m^3$ is 87% of the 150 $\mu g/m^3$ standard. With monitored 24-hour PM_{10} concentrations in the vicinity of the Paducah site in the range of 50 to 60 $\mu g/m^3$, the estimated maximum concentration from construction of the yard could raise the total above the standard. The construction fugitive dust

TABLE D.12 Maximum Concentrations of Criteria Pollutants at Site Boundaries during Yard Construction[a]

	Estimated Maximum Criteria Pollutants							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]
Paducah Site								
CO	220	0.0055	112	0.011	37.3	–	4.76	–
HC[c]	22.5	–	11.5	–	3.84	–	0.489	–
NO_x	85.0	–	43.4	–	14.5	–	1.85	0.02
SO_x	9.02	–	4.59	–	1.53	–	0.196	0.003
PM_{10}	768	–	391	–	131	0.87	16.7	0.33
K-25 Site								
CO	266	0.0067	122	0.012	41.1	–	7.66	–
HC[c]	27.3	–	12.5	–	4.22	–	0.787	–
NO_x	103	–	47.1	–	15.9	–	2.97	0.03
SO_x	10.9	–	5.00	–	1.69	–	0.315	0.004
PM_{10}	930	–	425	–	144	0.96	26.8	0.54

[a] Paducah values are based on reconstruction of the L-yard; K-25 values are based on construction of a new yard assumed to be located at the site of the current K-yard. No yard construction is planned for the Portsmouth site.

[b] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

[c] HC, although not a criteria pollutant, was used to evaluate potential impacts to the criteria pollutant ozone.

emissions used here were based on a general emission factor that considers only the size of the disturbed area and might be an overestimate for the actual use of construction equipment on the site.

Detailed information about the planned construction would be required to more accurately assess the likely actual impacts. However, because the construction site would be adjacent to the facility boundary, it is likely that some measures would be required to reduce the generation of fugitive dust during reconstruction of the yard. Other estimated pollutant concentrations are much smaller fractions of their respective standards, in general being of the order of 1 to 2% of the standard.

Relocating and painting cylinders would involve powered units that produce internal combustion emissions. The paint to be used on the cylinders would be an additional source of volatile organic compound (VOC) emissions (HC is an indicator of VOC sources). Because the relocation and painting of cylinders would generally occur at several locations for each site, emissions from those activities were modeled as point sources at the centers of the sites. The maximum number of annual cylinder relocations that would be required at Paducah during the no action alternative would be 4,200; the maximum number of cylinders painted annually would be 3,000. Table D.13 gives the estimated maximum concentrations of criteria pollutants at the Paducah site boundaries due to relocations; Table D.14 gives the estimated maximum concentrations due to painting activities.

Assumptions regarding the number of hypothetical cylinder breaches were used to estimate maximum annual HF emissions (Tschanz 1997b); these estimates are listed in Table D.15. The estimated 0.01 μg/m³ maximum HF concentration at the Paducah site boundary is considerably below the Kentucky primary annual standard for HF of 0.5 ppm (400 μg/m³).

TABLE D.13 Maximum Concentrations of Criteria Pollutants at Site Boundaries due to Cylinder Relocations[a]

	Estimated Maximum Criteria Pollutants							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration (μg/m³)	Fraction of Standard[b]	Concentration (μg/m³)	Fraction of Standard[b]	Concentration (μg/m³)	Fraction of Standard[b]	Concentration (μg/m³)	Fraction of Standard[b]
Paducah Site								
CO	13.3	0.0033	1.66	0.00017	0.554	–	0.0244	–
HC[c]	1.07	–	0.134	–	0.0448	–	0.00197	–
NO_x	1.59	–	0.199	–	0.0665	–	0.00292	0.00003
SO_x	3.84	–	0.482	–	0.161	–	0.00706	0.00009
PM_{10}	0.337	–	0.0423	–	0.0141	0.0009	0.000620	0.00001
K-25 Site								
CO	5.36	0.00013	1.40	0.00014	0.469	–	0.0277	–
HC[c]	0.434	–	0.113	–	0.0379	–	0.00224	–
NO_x	0.643	–	0.168	–	0.0562	–	0.00332	0.00003
SO_x	1.55	–	0.405	–	0.136	–	0.00803	0.0001
PM_{10}	0.136	–	0.0356	–	0.0119	0.00008	0.000705	0.00001

[a] Cylinder relocations are planned for the Paducah and K-25 sites during the time frame considered (1999-2039).

[b] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

[c] HC, although not a criteria pollutant, was used to evaluate potential impacts to the criteria pollutant ozone.

TABLE D.14 Maximum Concentrations of Criteria Pollutants at Site Boundaries due to Cylinder Painting[a]

	Estimated Maximum Criteria Pollutants							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]
Paducah Site								
CO	9.48	0.00024	1.19	0.00012	0.396	–	0.0174	–
HC[c]	127	–	15.9	–	5.31	–	0.233	–
NO_x	1.13	–	0.142	–	0.0472	–	0.0021	0.000021
SO_x	2.75	–	0.344	–	0.115	–	0.0050	0.000064
PM_{10}	0.244	–	0.031	–	0.0102	0.000068	0.00045	0.000009
Portsmouth Site								
CO	3.72	0.000093	0.583	0.000058	0.205	–	0.018	–
HC[c]	49.9	–	7.84	–	2.76	–	0.236	–
NO_x	0.445	–	0.070	–	0.025	–	0.0021	0.000021
SO_x	1.08	–	0.170	–	0.060	–	0.0051	0.000065
PM_{10}	0.097	–	0.015	–	0.0053	0.000035	0.00046	0.000092
K-25 Site								
CO	2.75	0.000069	0.716	0.000072	0.240	–	0.014	–
HC[c]	36.8	–	9.59	–	3.22	–	0.190	–
NO_x	0.321	–	0.084	–	0.028	–	0.0017	0.000017
SO_x	0.803	–	0.209	–	0.070	–	0.0042	0.000054
PM_{10}	0.064	–	0.017	–	0.0056	0.000037	0.00033	0.0000066

[a] Maximum pollutant concentrations are based on the maximum number of cylinders painted annually under the no action alternative: 3,000 at Paducah; 1,350 at Portsmouth; and 1,200 at K-25.

[b] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

[c] HC, although not a criteria pollutant, was used to evaluate potential impacts to the criteria pollutant ozone.

TABLE D.15 Estimated Number of Breached Cylinders, Maximum HF Emissions, and Average Maximum HF Concentrations at the Existing Storage Sites under the No Action Alternative

Site	Maximum Number of Breaches Starting in a Single Year	Maximum Total Number of Active Breaches in a Single Year	Maximum HF Concentration ($\mu g/m^3$)	
			24-Hour Average	Annual Average
Paducah	2	5	0.08	0.0093
Portsmouth	2	3	0.10	0.011
K-25	1	2	0.66	0.084

No quantitative estimate was made of the impacts on the criteria pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the Paducah site. McCracken County in the Paducah-Cairo Interstate Air Quality Control Region is currently in attainment for all criteria pollutant standards, including ozone. The pollutants most related to ozone formation that could result from the continued storage options at the Paducah site would be HC and NO_x. The potential effects on ozone of those emissions can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in McCracken County, as recorded in the Kentucky Division of Air Quality Control "Emissions Inventory" for 1995 (Hogan 1996). The estimated maximum annual HC and NO_x emissions of 7.11 and 1.47 tons/yr would be only 1.2 and 0.004%, respectively, of the 1995 McCracken County emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the county.

D.2.3.2 Portsmouth Site

Because no storage yard construction is planned at the Portsmouth site, the maximum pollutant impacts, other than for HC, estimated at the facility boundary are much smaller than those estimated for the other two sites. The maximum criteria pollutant concentrations are shown in Table D.14; criteria pollutant emissions for Portsmouth are associated only with painting activities. For all pollutants, including PM_{10}, the concentrations are less than 0.1% of the standards. As shown in Table D.15, the HF concentrations would likewise be small (Tschanz 1997b). The State of Ohio does not have an ambient air quality standard for HF.

No quantitative estimate was made of the impacts on the criteria pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the Portsmouth site. Pike and Scioto Counties in the Wilmington-Chillicothe-Logan Air Quality Control Region are currently in attainment for all criteria pollutant standards, including ozone. The pollutant emissions most related to ozone formation that could result from continued cylinder storage at the Portsmouth site would be HC and NO_x. The potential effects on ozone of those emissions can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in Pike and Scioto Counties, as recorded in the Ohio Environmental Protection Agency "Emissions Inventory" for 1990 (Juris 1996). The estimated HC and NO_x emissions of 3.01 and 0.05 tons/yr from continued storage actions would be only 0.18 and 0.002%, respectively, of the 1990 two-county emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region.

D.2.3.3 K-25 Site

The maximum estimated criteria pollutant concentrations at the K-25 boundary during yard construction are shown in Table D.12. These maximum concentrations would occur when the planned new storage yard would be completed. The maximum monitored 24-hour PM_{10} concentration at the Y-12 site is about 29 $\mu g/m^3$, which when added to the estimated maximum PM_{10} concentration at the K-25 site brings the total above the 150 $\mu g/m^3$ standard. The qualifications regarding the estimated PM_{10} concentrations and the likelihood for a need of mitigative measures discussed above for the Paducah site also apply to these K-25 results. As for Paducah, all other criteria pollutant concentrations at K-25 would be well below their respective standards, generally being between 1 to 3% of the standard. For years during which no construction activities are planned, the maximum pollutant concentrations should not exceed air quality standards (Tables D.13 and D.14).

The maximum annual and 24-hour average HF concentrations from hypothetical cylinder breaches at K-25 are estimated to be the highest of the three storage sites, as shown in Table D.15 (Tschanz 1997b). In large part, these high concentrations are a result of the distance to the nearest facility boundary from the modeled location, which for the majority of HF point source emissions is shorter at the K-25 site than at either of the other two facilities. The estimated maximum 24-hour HF concentrations would be 0.66 $\mu g/m^3$, which is 23% of the State of Tennessee standard of 2.9 $\mu g/m^3$. The highest monitored 7-day HF concentration at the Y-12 site in 1992 was 0.28 $\mu g/m^3$.

No quantitative estimate was made of the impacts on the criteria pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the K-25 site. Anderson and Roane Counties in the Eastern Tennessee-Southwestern Virginia Interstate Air Quality Control Region are currently in attainment for all criteria pollutant standards, including ozone. The pollutant emissions most related to ozone formation that could result from the continued storage options at the K-25 site would be HC and NO_x. The potential effects on ozone of those pollutants can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in Anderson and Roane Counties, as recorded in the Tennessee Division of Air Pollution Control "Emissions Inventory" for 1995 (Conley 1996). The estimated HC and NO_x emissions of 3.03 and 1.24 tons/yr would be only 0.11 and 0.002%, respectively, of the 1995 two-county emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region. The HC and NO_x emissions would be even smaller during later continued storage periods.

D.2.4 Water and Soil

Potential water and soil impacts for continued storage of cylinders under the no action alternative were evaluated for surface water, groundwater, and soils at each of the three storage facilities. Impacts to water and soil quality were evaluated by comparisons with U.S. Environmental Protection Agency (EPA) guidelines.

Water use for construction under the no action alternative was estimated to be 2 million gal for the Paducah site and 0.81 million gal for the K-25 site (no construction would occur at the Portsmouth site). Operational water use was estimated as ranging from 0.12 to 0.16 million gal/yr at Paducah, 0.055 to 0.06 million gal/yr at Portsmouth, and 0.025 to 0.032 million gal/yr at K-25.

D.2.4.1 Surface Water

The estimated number of cylinder breaches assumed to occur under the no action alternative is given in Appendix B; these estimates were used to calculate potential impacts to surface water quality. Each breached cylinder was assumed to release a maximum of 4 lb (1.8 kg) of uranium over a period of 4 years; additional details on the methodology used to evaluate the impacts are given in Appendix C and Tomasko (1997b).

The estimated maximum uranium concentrations in runoff water leaving the yards would be about 20, 19, and 52 µg/L (5, 5, and 13 pCi/L) for Paducah, Portsmouth, and K-25, respectively. These concentrations would occur in about 2002. The contaminated runoff was then assumed to flow without loss to the nearest surface water, where it would mix and be diluted. For average flow conditions, the dilution would be large enough that the maximum concentrations would be less than 0.7 µg/L (0.2 pCi/L) for all three sites (Table D.16). This concentration is less than the EPA proposed drinking water maximum contaminant level (MCL) for uranium of 20 µg/L, used here for comparison. The contaminated water would then mix with water in the Ohio River, Scioto River, or Clinch River, resulting in even greater dilution. Because of this mixing, impacts to the major rivers would not be measurable.

D.2.4.2 Groundwater

Groundwater impacts were assessed by assuming that water contaminated due to releases from hypothetical cylinder breaches would leave the yards as runoff and flow to the boundary of the nearest surface water (but not discharge to it), thereby creating a contaminated source on the ground surface. On the basis of the assumption that cylinder painting would control corrosion, the only impacts to groundwater would be to water quality; no impacts would occur to recharge, depth to water, or direction of flow (see Section D.3 for discussion of potential impacts based on assuming a greater number of breaches). Conservative estimates of the concentration of uranium in

TABLE D.16 Maximum Uranium Concentrations in Surface Waters for Continued Cylinder Storage under the No Action Alternative

Site	Receiving Water	Dilution Factor	Maximum Concentration (µg/L)
Paducah	Little Bayou Creek	124	0.3
	Ohio River	43,600	0.000004
Portsmouth	Little Beaver Creek	26	0.7
	Scioto River	2,240	0.0004
K-25	Poplar Creek	2,550	0.02
	Clinch River	94	0.0002

groundwater were obtained by assuming the surface value to be equal to the maximum concentration in water leaving each yard during a time interval of approximately 40 years. This duration corresponds to the time period for the no action alternative. Details on the methodology are given in Appendix C and Tomasko (1997b).

At the end of the no action period (2039), the concentrations of uranium in groundwater directly below the edge of the surface contamination at the Paducah, Portsmouth, and K-25 sites were estimated to be about 0.25, 0.1, and 0.6 µg/L, respectively (Table D.17), for a retardation factor of 5 (Tomasko 1997b). These concentrations are less than the EPA proposed drinking water MCL for uranium of 20 µg/L (EPA 1996). Maximum concentrations of 6, 5, and 7 µg/L would occur at the Paducah, Portsmouth, and K-25 sites, respectively, between 2070 and 2090 (Table D.17). For a retardation factor of 50 (relatively immobile uranium transport), maximum concentrations would be about 10 times less.

D.2.4.3 Soil

Estimated numbers of cylinder breaches assumed to occur under the no action alternative were used to calculate impacts to soil quality. Each breached cylinder was assumed to release a maximum of 1 lb/yr (0.45 kg/yr) for a maximum of 4 years. For soil, the only impacts would be to quality; there would be no impacts to topography, permeability, or erosion potential. Details on these calculations and methodology are presented in Appendix C and Tomasko (1997b).

At the Paducah site, the highest soil concentration of uranium would be 0.1 µg/g in about 2002 for a distribution coefficient (K_d) of 5 (relatively low sorption capacity). If the soil had a larger

TABLE D.17 Groundwater Concentrations for Continued Cylinder Storage for Two Soil Characteristics under the No Action Alternative[a]

	X = 0			X = 1,000 ft		
	Concentration		Time at Maximum Concentration	Concentration		Time at Maximum Concentration
Site/Parameter	pCi/L	µg/L		pCi/L	µg/L	
Retardation Factor = 5						
Paducah						
Concentration at 40 years	0.07	0.25				
Maximum concentration	2	6.1	70 years	1.3	4.9	90 years
Portsmouth						
Concentration at 40 years	0.03	0.10				
Maximum concentration	1	5.1	80 years	1.1	4.1	96 years
K-25						
Concentration at 40 years	0.2	0.60				
Maximum concentration	2	7.3	60 years	1.5	5.7	80 years
Retardation Factor = 50						
Paducah						
Maximum concentration	0.2	0.7	585 years	0.1	0.5	770 years
Portsmouth						
Maximum concentration	0.1	0.5	670 years	0.1	0.4	860 years
K-25						
Maximum concentration	0.2	0.8	500 years	0.2	0.6	675 years

[a] Retardation factors describe how readily a contaminant such as uranium moves through the soil in groundwater. A retardation factor of 5 represents a case in which the uranium moves relatively rapidly in the soil; a retardation factor of 50 represents a case in which uranium moves slowly.

sorption capacity (K_d = 50), the maximum value would be 10 times greater (1.0 µg/g). At the Portsmouth site, the highest soil concentration of uranium would be 0.09 µg/g in about 2002 for a distribution coefficient of 5 (relatively low sorption capacity). If the soil had a larger sorption capacity (K_d = 50), the maximum value would be 10 times greater, 0.9 µg/g. At the K-25 site, the highest soil concentration of uranium would be 0.3 µg/g in about 2002 for a distribution coefficient of 5 (relatively low sorption capacity). If the soil had a larger sorption capacity (K_d = 50), the maximum value would be 3.0 µg/g. Even with the larger sorption, soil concentrations at the three sites would be below the recommended EPA guideline of 230 µg/g for residential soil and 6,100 µg/g for industrial soil (EPA 1995).

D.2.5 Socioeconomics

The impacts of continued storage on regional economic activity were estimated for a region of influence (ROI) at each of the three storage sites. Additional details regarding the assessment methodology are presented in Appendix C and Allison and Folga (1997).

Current storage activities at each site would likely have a small impact on socioeconomic conditions in the ROIs surrounding the three sites (see Chapter 3, Sections 3.1.8, 3.2.8, and 3.3.8). This is partly because a major proportion of expenditures associated with procurement for conducting continued storage activities would flow outside the ROI to other locations in the United States, thereby reducing the concentration of local economic effects of current storage activities at each site.

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

The effects of continued cylinder storage activities on regional economic activity, measured in terms of employment and personal income, and on population, housing, and local public revenues and expenditures are discussed in Sections D.2.5.1 through D.2.5.3. Impacts are presented for each storage site during the peak year of construction and the peak year of operations. The potential impacts of continued cylinder storage at the three sites are shown in Table D.18.

D.2.5.1 Paducah Site

During the peak year for construction and reconstruction of cylinder yards, 20 direct jobs would be created at the site and 60 additional jobs indirectly in the ROI (Table D.18) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 80 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with $2.0 million of total income produced during the peak year. During the peak year of continued cylinder storage activities, 90 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, at a total income of $2.3 million. Continued storage activities would result in an increase of 0.005 percentage points in the projected baseline compound annual average growth rate in ROI employment from 1999 through 2039.

Construction activities would be expected to generate direct in-migration of 20 in the peak year (Table D.18). Additional indirect job in-migration would also be expected, bringing the total

TABLE D.18 Potential Socioeconomic Impacts of Continued Cylinder Storage under the No Action Alternative

Parameter	Paducah Site		Portsmouth Site		K-25 Site	
	Impacts from Construction[a]	Impacts from Operations[b]	Impacts from Construction[c]	Impacts from Operations[b]	Impacts from Construction[a]	Impacts from Operations[b]
Economic activity in the ROI						
Direct jobs	20	60	–	20	10	30
Indirect jobs	60	30	–	10	50	50
Total jobs	80	90	–	30	60	90
Income ($ million)						
Direct income	1.0	1.8	–	0.6	0.4	2.7
Total income	2.0	2.3	–	0.7	1.5	3.7
Population in-migration into the ROI	70	30	–	10	20	30
Housing demand						
Number of units in the ROI	20	10	–	0	10	10
Public finances						
Change in ROI fiscal balance (%)	0.0	0.0	–	0.0	0.0	0.0

[a] Impacts for peak construction year. Construction activities were assumed to occur over 4 years at the Paducah site and over 1 year at the K-25 site (Parks 1997).

[b] Impacts for peak year of operations. Duration of operations was assumed to be 41 years (1999-2039).

[c] No construction activities are planned for continued cylinder storage at the Portsmouth site.

number of in-migrants to 70 in the peak year. Continued cylinder storage activities would be expected to generate direct and indirect job in-migration of 30 in the peak year of operations and would result in an increase of 0.001 percentage points in the projected baseline compound annual average growth rate in the ROI population from 1999 through 2039.

Continued cylinder storage activities would generate the demand for 20 additional rental housing units during the peak year of construction, representing an impact of 1.6% on the projected number of vacant rental housing units in the ROI (Table D.18). The demand for 10 additional owner-occupied housing units would be expected in the peak year of operations and would represent an impact of 0.3% on the number of vacant owner-occupied housing units.

During the peak year of construction, 70 persons would in-migrate into the ROI, which would lead to an increase of 0.04% over ROI-forecasted baseline revenues and expenditures (Table D.18). In the peak year of operations, 30 in-migrants would be expected, which would result in a 0.02% increase in local revenues and expenditures.

D.2.5.2 Portsmouth Site

During the peak year of continued cylinder storage activities, 20 direct jobs would be created at the site and 10 additional jobs indirectly in the ROI (Table D.18) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 30 jobs would be created. Operations would also produce direct and indirect income in the ROI surrounding the site, at a total income of $0.7 million during the peak year. Continued cylinder storage operations would result in an increase of 0.001 percentage points in the projected baseline compound annual average growth rate in ROI employment from 1999 through 2039.

Continued cylinder storage activities would be expected to generate direct in-migration of less than 10 in the peak year (Table D.18). Additional indirect job in-migration would also be expected and would bring the total number of in-migrants to 10 in the peak year. Operations would result in an increase of less than 0.001 percentage points in the projected baseline compound annual average growth rate in the ROI population from 1999 through 2039.

Continued cylinder storage activities would generate the demand for less than 10 additional rental housing units during the peak year of construction, thus representing an impact of 0.1% on the projected number of vacant rental housing units in the ROI (Table D.18).

During the peak year of operations, 10 persons would in-migrate into the ROI, thereby leading to an increase that rounds to 0.0% over ROI-forecasted baseline revenues and expenditures (Table D.18).

D.2.5.3 K-25 Site

During the single year during which construction activities are planned at the K-25 site, 10 direct jobs would be created at the site and 50 additional jobs indirectly in the ROI (Table D.18) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 60 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with $1.5 million in income produced during the year. During the peak year of continued cylinder storage activities, 90 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, at a total income of $3.7 million. Continued cylinder storage activities would result in an increase of less than 0.001 percentage points in the projected baseline compound annual average growth rate in ROI employment from 1999 through 2039.

Construction activities would be expected to generate direct in-migration of 10 in the construction year (Table D.18). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to 20 in the peak year. Continued cylinder storage activities would be expected to generate direct and indirect job in-migration of 30 in the peak year of operations and would result in an increase of less than 0.001 percentage points in the projected baseline compound annual average growth rate in the ROI population from 1999 through 2039.

Continued cylinder storage activities would generate the demand for 10 additional rental housing units during the construction year and would represent an impact of 0.2% on the projected number of vacant rental housing units in the ROI (Table D.18). The demand for 10 additional owner-occupied housing units would be expected in the peak year of operations and would represent an impact of 0.1% on the number of vacant owner-occupied housing units.

During construction, 20 persons would in-migrate into the ROI, which would lead to an increase of less than 0.1% over ROI-forecasted baseline revenues and expenditures (Table D.18). In the peak year of operations, 30 in-migrants would be expected, which would result in a 0.01% increase in local revenues and expenditures.

D.2.6 Ecology

Impacts to ecological resources during continued cylinder storage would be expected to be negligible. Analysis of potential impacts was based on exposure to airborne contaminants or contaminants released to soil, groundwater, or surface water. Predicted concentrations of contaminants in environmental media were compared to benchmark values of toxic and radiological effects to assess impacts to terrestrial and aquatic biota. A detailed discussion of assessment methodology is presented in Appendix C.

At all three sites, atmospheric emissions of criteria pollutants from cylinder storage yard activities — including cylinder painting, cylinder relocation, and new yard construction (at the

Paducah and K-25 sites) — would be well below levels harmful to biota, and impacts to ecological resources would be negligible. (See Section D.2.3 for a discussion of air quality impacts and Appendix C for application of predicted values.)

The maximum annual average air concentration of HF at the site boundary, due to hypothetical cylinder breaches, would be very low, up to 0.08 $\mu g/m^3$ at the K-25 site and less for the other two sites (Section D.2.3). Resulting impacts to biota would be expected to be negligible. Potential impacts to ecological resources are shown in Table D.19.

Soil near the storage yards could become contaminated with uranium by surface runoff from the yards. Uptake of uranium-containing compounds can cause adverse effects to vegetation. The potential maximum uranium concentration in soil would be 1.0 µg/g at the Paducah site, 0.9 µg/g at the Portsmouth site, and 3.0 µg/g at the K-25 site (Section D.2.4.3). Because these estimated concentrations are below the lowest concentration known to produce toxic effects in plants, toxic effects on vegetation due to uranium uptake would not be expected (Table D.19).

Surface runoff from the storage yards would result in maximum (undiluted) uranium concentrations of 20, 19, and 52 µg/L (5.2, 4.8, and 13.4 pCi/L) at the Paducah, Portsmouth, and K-25 sites, respectively (Section D.2.4.1). Resulting dose rates to maximally exposed organisms in the nearest receiving surface water body at each site would be less than 0.016 rad/d, less than 2% of the dose limit of 1 rad/d for aquatic organisms, as specified in DOE Order 5400.5. These uranium concentrations are also considerably below 150 µg/L, which is the lowest concentration known to adversely affect aquatic biota. Therefore, impacts to aquatic biota would not be expected.

Surface runoff from the storage yards could infiltrate adjacent soil and become a source of groundwater contamination. Groundwater could discharge to the surface (such as in wetland areas) near the facility, thus exposing biota to contaminants. Groundwater concentrations of uranium near the storage yards could range up to 6.1, 5.1, and 7.3 µg/L at the Paducah, Portsmouth, and K-25 sites, respectively; uranium activity could range up to 2, 1, and 2 pCi/L, respectively (Section D.2.4.2). Resulting toxic effects and dose rates to maximally exposed organisms would be negligible. Resulting impacts to aquatic biota would therefore be negligible (Table D.19).

Facility accidents (Section D.2.2) 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.

D.2.7 Waste Management

The principal wastes expected to be generated by operations involving continued cylinder storage are low-level radioactive waste (LLW) and low-level mixed waste (LLMW). Impacts on waste management from wastes generated during the continued storage operations at the sites would be caused by the potential overload of waste treatment and/or disposal capabilities either at a site or

TABLE D.19 Potential Impacts to Ecological Resources from Continued Cylinder Storage under the No Action Alternative

Contaminant	Biota	Maximum Exposure	Effect
Paducah Site			
Hydrogen fluoride	Wildlife	0.009 μg/m^3	Negligible
Uranium in surface water	Aquatic	20 μg/L	Negligible
		5.2 pCi/L	Negligible
Uranium in groundwater	Aquatic	6.1 μg/L	Negligible
		1.6 pCi/L	Negligible
Uranium in soil	Plants	1.0 μg/g	Negligible
Portsmouth Site			
Hydrogen fluoride	Wildlife	0.01 μg/m^3	Negligible
Uranium in surface water	Aquatic	19 μg/L	Negligible
		4.8 pCi/L	Negligible
Uranium in groundwater	Aquatic	5.1 μg/L	Negligible
		2.1 pCi/L	Negligible
Uranium in soil	Plants	0.9 μg/g	Negligible
K-25 Site			
Hydrogen fluoride	Wildlife	0.08 μg/m^3	Negligible
Uranium in surface water	Aquatic	52 μg/L	Negligible
		13 pCi/L	Negligible
Uranium in groundwater	Aquatic	7.3 μg/L	Negligible
		1.9 pCi/L	Negligible
Uranium in soil	Plants	3.0 μg/g	Negligible

on a regional/national scale. Waste generated at the three sites from continued cylinder storage under the no action alternative are listed in Table D.20. Given the types and quantities of waste expected to be generated, there is little potential for impacts on regional or national waste treatment/disposal capabilities.

Only limited construction of additional facilities would be needed to support the operations involved in the continued storage and maintenance of cylinders. No waste management impacts resulting from construction-generated wastes would be expected.

The normal operations to maintain and store cylinders would consist of inspections, stripping and repainting of the cylinders, and disposal of scrap metal from breached cylinders that required emptying. These operations would generate two primary waste streams: (1) uranium-contaminated scrap metal LLW from breached cylinders and failed valves and (2) solid process residue LLMW from cylinder painting. In the event of cylinder failure, small amounts of additional LLMW could be generated due to releases from breached cylinders.

For all three current storage sites, the amount of LLW generated from continued storage would at most represent less than 1% of site LLW generation (see Appendix C, Section C.10.2). The maximum annual amount of LLW generated during the continued storage of cylinders at all three sites would represent less than 1% of the annual DOE LLW generation.

Continued storage would also generate LLMW at all three sites. At the Paducah site, stripping/painting operations would generate a maximum annual amount of 23 m^3 of LLMW, which

TABLE D.20 Waste Generated during Continued Cylinder Storage under the No Action Alternative

	Waste (m^3)	
Site	LLW[a]	LLMW[b]
Paducah	52	893
Portsmouth	23	418
K-25	10	157
Total (1999-2039)	85	1,468

[a] Contaminated scrap metal from empty cylinders.

[b] Inorganic process residues from cylinder painting.

would be about 20% of the site's total annual LLMW load, which represents a moderate impact to site waste management capabilities. At the Portsmouth site, the LLMW input would be less than 1% of the site load. At the K-25 site, continued cylinder storage would generate less than 1% of the total LLMW load at the Oak Ridge Reservation. Overall, the waste input resulting from continued cylinder storage would have negligible impacts on waste management capabilities at the Portsmouth and K-25 sites, but impacts from disposal of LLMW could have moderate impacts at the Paducah site. Impacts on national waste management capabilities would be negligible. The input of LLMW from continued cylinder storage at the three sites would represent less than 1% of the total nationwide LLMW load.

D.2.8 Resource Requirements

Material resources that could be consumed during continued cylinder storage include construction materials that could not be recovered or recycled, and materials consumed or reduced to unrecoverable forms of waste. Where construction is necessary, materials required could include concrete, sand, gravel, steel, and other metals. In general, none of the construction resources identified for continued cylinder storage are in short supply, and all would be readily available in the vicinity of the three sites. Energy resources during construction and operations would include the consumption of diesel fuel and gasoline for construction equipment and transportation vehicles. The anticipated utilities requirements would be within the supply capacities at each site. Detailed information relating to the methodology is presented in Appendix C.

Cylinder yard construction or reconstruction would occur only at the Paducah and K-25 sites. No reconstruction activities are anticipated at the Portsmouth site.

Continued cylinder storage would require materials such as 55-gal drums for containment of any generated waste, replacement cylinder valves for those found to be defective upon inspection, and diesel fuel and gasoline to operate equipment and on-site vehicles. In addition, two gallons of paint per cylinder would be required for cylinder painting. Potable water would be made available for the needs of the workforce.

Materials and utilities required for construction and operation activities for continued storage at the Paducah, Portsmouth, and K-25 sites are presented in Table D.21. The total quantities of commonly used construction materials are expected to be small compared to local sources. No strategic and critical materials are projected to be consumed for either construction or operations. Small amounts of diesel fuel and gasoline are projected to be used. The required material resources during operations would be readily available.

D.2.9 Land Use

No construction activities are planned for the Portsmouth site. Other than disturbances to

TABLE D.21 Resource Requirements of Construction and Operations for Continued Cylinder Storage under the No Action Alternative

		Consumption during 1999-2039		
Materials/Resource	Unit	Paducah Site	Portsmouth Site	K-25 Site
Construction				
Solids				
Concrete	yd^3	20,000	0	8,000
Construction aggregate	yd^3	29,000	0	12,000
Special coatings	yd^2	90,000	0	36,000
Liquids				
Gasoline	gal	3,100	0	1,300
Diesel fuel	gal	18,000	0	7,300
Operations[a]				
Solids				
55-gal drums	each	104 – 109	50	18 – 20
Cylinder valves (1-in.)	each	9	4	2
Liquids				
Gasoline	gal/yr	3,400 – 4,500	1,600 – 1,700	700 – 1,000
Diesel fuel	gal/yr	8,600 – 13,600	4,100	1,500 – 2,600
Zinc-based paint	gal/yr	5,700 – 6,000	2,700	1,000 – 1,100

[a] Values reported as ranges generally correspond to varying resource requirements during years for which construction activities are planned.

be necessary at the Paducah site. Construction activities at Paducah would consist of modifications to existing yards; no new construction would occur outside the footprints of existing yards. Although no location has been chosen for a new storage yard at K-25, the areal requirement of 6.7 acres (2.7 ha) would be very small and represent less than 1% of the land available for development on the site. Because the yard would be located in an area already dedicated to similar use, immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land use.

During continued cylinder storage operations, land-use impacts at the three sites would be negligible and limited to potential minor disruptions on land parcels contiguous to the existing yards. No impacts would be expected for off-site land use.

D.2.10 Cultural Resources

Impacts to cultural resources are not likely at the Paducah or Portsmouth sites during continued cylinder storage. The existing and proposed storage yards at Paducah are located in previously disturbed areas unlikely to contain cultural properties or resources eligible for the *National Register of Historic Places*. No new storage yards are proposed at Portsmouth, so no cultural resources would be affected. A new storage yard is proposed at the K-25 site; however, the exact location is unknown. Impacts might result if the storage yard was constructed on or near an eligible resource.

D.2.11 Environmental Justice

The analysis of potential environmental justice impacts resulting from continued cylinder storage is based on the conclusions drawn in the assessment of impacts on human health (Sections D.2.1 and D.2.2) and a review of environmental impacts presented in discussions of other technical areas (Sections D.2.3 through D.2.10) such as air quality, water quality and soils, socioeconomics, and ecological resources. The analysis of health effects included an examination of risks to the general public associated with normal facility operations and accidents. A detailed description of the mapping procedures, screening criteria, calculational methods, and demographic sector analysis is presented in Appendix C, Section C.8.

Events occurring after 2039 could not be included in the analysis of potential environmental justice impacts because the composition of the population residing within 50 miles (80 km) of a site cannot be projected with accuracy over the long term. Current minority and low-income population proportions for each site were assumed out to the year 2039.

A review of potential human health impacts (Sections D.2.1 and D.2.2) indicated that no high and adverse human health effects or impacts would be expected from continued storage of cylinders at the Paducah, Portsmouth, and K-25 sites. Therefore, although minority and low-income populations reside within 50 miles (80 km) of the sites, no disproportionate impacts would be expected. The distributions of minority and low-income population census tracts within a 50-mile (80-km) radius of each site are shown in Appendix C, Figures C.1 through C.3. Screening criteria limits (Appendix C, Section C.8) for radiological and chemical sources under normal operations and accident conditions were not exceeded, and the risk of fatalities from operations and accidents from 1999 through 2039 would be considerably below one. Radiological releases from normal operations at the three sites would result in annual average doses to the MEI residing outside the facilities that would be considerably below the DOE regulatory limit of 100 mrem/yr for members of the public. Chemical impacts from routine operations under continued storage at all three sites would result in MEI hazard indices well below 1. Additionally, accidental chemical releases would not result in any expected fatalities or expected adverse human health effects for the general public (when considering risk, i.e., the product of the potential number of persons affected and the probability of the accident occurring).

A review of impact assessments for other technical areas (Sections D.2.3 through D.2.10) indicated that few or no impacts would be expected from continued storage of cylinders at any of the sites. Projected air emissions from construction activities and operations would be below federal and state regulatory limits and no impacts to water quality or soils are anticipated. Consequently, no segment of the population, including minorities or persons of low-income, would experience disproportionate impacts.

D.2.12 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur as a result of continued storage of depleted UF_6 cylinders at the three current storage sites include impacts to the visual environment (e.g., aesthetics), recreational resources, and noise levels, as well as impacts associated with decontamination and decommissioning of the storage yards. These impacts, although considered, were not analyzed in detail because the impacts would be negligibly small or consideration of the impacts would not contribute to differentiation among the alternatives and therefore would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS.

D.3 POTENTIAL IMPACTS OF CONTINUED CYLINDER STORAGE BASED ON UNCERTAINTIES IN CORROSION CONTROL

Under the no action alternative, it was assumed that cylinders would be painted every 10 years and that the paint would effectively stop any further corrosion of the cylinders (see introduction to this appendix). To address uncertainty in both the effectiveness of the painting in controlling further corrosion and uncertainties in the future painting schedule, a conservative assessment was made of the impacts assuming that painting would have no effect on corrosion. Under this assumption and using historical data from the three sites, the number of breaches that would occur at each site as a function of time were estimated (Lyon 1997). These conservative estimates indicate that the number of breaches that could occur prior to 2039 would be about 400 at Paducah, 74 at Portsmouth, and 210 at K-25 (see Appendix B).

If no credit were taken for corrosion reduction through painting, and if storage was continued at the three current storage sites indefinitely, calculations indicate that uranium releases from breaches occurring at the Paducah site prior to about the year 2020 could result in a sufficient amount of uranium in the soil column to bring the groundwater concentration of uranium to 20 μg/L in the future (about 2100) (Tomasko 1997a). The cylinders would have to undergo uncontrolled corrosion (without painting) until about 2050 at Portsmouth, and until about 2025 at the K-25 site before the same groundwater concentration guideline of 20 μg/L would be a concern. Again, the groundwater concentration would not actually reach 20 μg/L at these sites until about 2100 or later.

Also, if no credit were taken for corrosion reduction through painting, air quality concerns might arise. Calculations indicate that breaches occurring at the K-25 site by around the year 2020 could result in maximum 24-hour average HF concentrations at the site boundary approximately equal to 2.9 μg/m³ (3.5 ppb). This level corresponds to the primary standard for the State of Tennessee. For comparison, the maximum estimated 24-hour average HF concentration at the Paducah and Portsmouth sites through the year 2039 would be 2 μg/m³ and 0.6 μg/m³, considerably below the 2.9 μg/m³ level (the State of Kentucky primary standard for HF is much higher [816 μg/m³ maximum 24-hour average]; the State of Ohio does not have standards for HF).

A painting program for the cylinders, designed to control further corrosion, has been initiated at the three sites. Therefore, the assumption of uncontrolled corrosion is not a reasonable assumption. The painting program is expected to eliminate or substantially reduce the corrosion of cylinders at the sites. DOE will continue to monitor its cylinders and is committed to maintain the safety basis of continued cylinder storage. If the conditions became substantially different from what is assumed under the no action alternative, DOE would take the appropriate action(s) to maintain the safety basis.

D.4 POTENTIAL IMPACTS OF CONTINUED CYLINDER STORAGE FOR THE ACTION ALTERNATIVES

For the action alternatives considered in this PEIS — long-term storage as UF_6, long-term storage as uranium oxide, use as uranium oxide, use as uranium metal, and disposal as uranium oxide — continued storage could be necessary for some portion of the DOE-generated cylinders at the current storage sites through approximately 2028. This 30-year storage period would correspond to the period during which construction of conversion, long-term storage, and/or disposal facilities would occur and during which the cylinders would be transported from the current locations to the processing locations. For analyses in this PEIS, the cylinder removal period was assumed to take place between 2009 and 2028; the number of cylinders at each site would decrease by 5% annually during that time.

Potential environmental impacts associated with continued cylinder storage for the action alternatives were assessed with essentially the same methodology used to estimate impacts for the no action alternative (see Section D.2 and Appendix C). Through the year 2008, the number of maintenance activities (such as inspections, yard reconstruction, and painting) was assumed to be the same as for the no action alternative (Parks 1997). From 2009 through 2028, the number of maintenance activities was assumed to decrease by 5% annually, to correspond to the reduction in cylinder inventory that would be occurring. Impacts associated with maintenance activities (e.g., radiation doses to involved workers) would, therefore, generally be reduced for the action alternatives.

A key difference between the assessment of continued storage impacts conducted for the action alternatives and the assessment conducted for the no action alternative was in the assumptions made regarding potential numbers of breached cylinders. Because of impending cylinder movement or content transfer, cylinder yard improvement and cylinder painting might not occur at the same rate under the action alternatives as they would under the no action alternative. Because the painting schedule that would be followed under the action alternatives is not known, and to present reasonable upper bound estimates of impacts, no credit was taken for the effectiveness of cylinder yard improvements and painting in reducing cylinder corrosion rates. Therefore, the number of hypothetical cylinder breaches assumed for the action alternatives was estimated by assuming that painting and improved storage conditions were not effective in arresting continued corrosion of the cylinders (i.e., assuming that corrosion continued at historical rates; see Appendix B) and by assuming that the population of cylinders at each site was decreasing at an annual rate of 5% between the years 2009 and 2028. These assumptions led to a higher number of assumed breaches for continued storage under the action alternatives than under the no action alternative, even though the number of years of storage would be lower. The assumptions for releases of uranium and HF from breached cylinders, as well as for methods to estimate water and soil impacts, were identical to those used for the assessment of impacts for the no action alternative. However, the outcome of the increased number of assumed cylinder breaches was a slightly higher estimate of impacts on groundwater, air quality, and human health and safety for the action alternatives, although the estimated impacts are still within applicable standards or guidelines (see Table D.1). The impacts of continued cylinder storage under the action alternatives for the various technical areas of interest are discussed in Sections D.4.1 through D.4.11. Assessment methods are described in Appendix C and in Section D.2.

D.4.1 Human Health — Normal Operations

D.4.1.1 Radiological Impacts

Estimated radiation doses and latent cancer risks for each of the three storage sites are presented in Tables D.22 and D.23. Long-term radiological impacts (based on groundwater contamination) are provided in Table D.24.

D.4.1.1.1 Paducah Site

During the continued cylinder storage period, the average annual collective dose for involved workers would be about 15 person-rem/yr for an average of 23 workers, assuming the workers work 5 hours per day in the cylinder yard. The individual dose for involved workers would average 650 mrem/yr for this period of time. The maximum dose for noninvolved workers would be less than 0.3 mrem/yr, well below the regulatory limit of 10 mrem/yr. For the general public, the maximum dose would be approximately 0.1 mrem/yr, with 0.03 mrem/yr from airborne pathways and 0.07 mrem/yr from groundwater pathways.

Long-term radiation exposure after year 2028 from use of contaminated groundwater would result in a maximum dose of 1.3 mrem/yr, which is a small fraction of the DOE dose limit of 100 mrem/yr for the general public.

TABLE D.22 Radiological Doses from Continued Cylinder Storage under Normal Operations for the Action Alternatives

	Annual Dose to Receptor					
	Involved Workers[a]		Noninvolved Workers[b]		General Public	
Site	Average Individual Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[c] (mrem/yr)	Collective Dose[d] (person-rem/yr)	MEI Dose[e] (mrem/yr)	Collective Dose[f] (person-rem/yr)
Paducah	650	15	0.26	0.012	0.031 (< 0.072)	0.017
Portsmouth	450	6.0	0.057	0.00040	0.017 (< 0.0051)	0.0017
K-25	260	3.0	0.17	0.0031	0.37 (< 0.085)	0.017

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual dose and collective dose for the worker population. The reported values are averages over the time period 1999-2028. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[b] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

[c] The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest dose. The reported values are the maximums over the time period considered.

[d] The reported collective doses are averages over the time periods considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

[e] The MEI for the general public was assumed to be located off-site at a point that would yield the largest dose. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[f] Collective dose was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.23 Latent Cancer Risks from Continued Cylinder Storage under Normal Operations for the Action Alternatives

	Annual Risk of Latent Cancer Fatality to Receptor					
	Involved Worker[a]		Noninvolved Worker[b]		General Public	
Site	Average Individual Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[c] (risk/yr)	Collective Risk[d] (fatalities/yr)	MEI Risk[e] (risk/yr)	Collective Risk[f] (fatalities/yr)
Paducah	3×10^{-4}	6×10^{-3}	1×10^{-7}	5×10^{-6}	2×10^{-8} ($< 7 \times 10^{-9}$)	8×10^{-6}
Portsmouth	2×10^{-4}	2×10^{-3}	2×10^{-8}	2×10^{-7}	8×10^{-9} ($< 5 \times 10^{-10}$)	8×10^{-7}
K-25	1×10^{-4}	1×10^{-3}	7×10^{-8}	1×10^{-6}	2×10^{-7} ($< 8 \times 10^{-9}$)	9×10^{-6}

a Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual risk and collective risk for the worker population. The reported values are averages over the time period 1999-2028.

b Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

c The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest risk. The reported values are the maximums over the time period considered.

d The reported collective risks are averages over the time period considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

e The MEI for the general public was assumed to be located off-site at a point that would yield the largest risk. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

f Collective risk was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.24 Long-Term Radiological Impacts to Human Health from Continued Cylinder Storage under the Action Alternatives[a,b]

	Impact to MEI of General Public	
Storage Location	Radiation Dose[c] (mrem/yr)	Latent Cancer Risk[c] (risk/yr)
Paducah site	0.13 – 1.3	$6 \times 10^{-8} - 7 \times 10^{-7}$
Portsmouth site	0.021 – 0.21	$1 \times 10^{-8} - 1 \times 10^{-7}$
K-25 site	0.077 - 0.64	$4 \times 10^{-8} - 3 \times 10^{-7}$

[a] Long-term impacts correspond to the time after the year 2028.

[b] Long-term impacts would be caused by the potential use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. Contamination of groundwater would result from releases from hypothetically breached cylinders and the resulting infiltration of UO_2F_2 to the deeper soils, eventually reaching the groundwater (UO_2F_2 is the product of UF_6 reacting with moisture in air).

[c] Radiation doses and latent cancer risks are expressed as ranges, which would result from different transport speeds of uranium in soil. The reported values are the maximum values that would occur after 2028, assuming no mitigation action was taken.

D.4.1.1.2 Portsmouth Site

During the cylinder storage period (1999-2028), the average annual collective dose for involved workers would be 6.0 person-rem/yr for approximately 14 workers, resulting in an average individual dose of 450 mrem/yr. The doses for the MEIs of noninvolved workers and members of the general public would be less than 0.06 and 0.02 mrem/yr, respectively, from airborne emission of UO_2F_2. Additional exposure of the general public could be caused by use of contaminated groundwater; the maximal dose would be about 0.005 mrem/yr by the end of the cylinder storage period. The radiation exposure of involved workers would be much less than the regulatory limit of 5,000 mrem/yr; exposure of noninvolved workers and members of the general public would be quite small compared with the regulatory limits of 10 mrem/yr for airborne emissions and 100 mrem/yr for all exposure pathways for the general public.

Long-term radiation exposure after the year 2028 from the use of contaminated groundwater would result in a maximum dose of 0.21 mrem/yr.

D.4.1.1.3 K-25 Site

Radiation exposures of involved workers at the K-25 site would be less than those at the Paducah and Portsmouth sites because fewer cylinders would be managed at the K-25 site. During continued cylinder storage, involved workers would receive an average dose of 260 mrem/yr from performing cylinder maintenance activities. The average annual collective dose for involved workers would be 3.0 person-rem/yr for approximately 12 workers. Radiation exposures of noninvolved workers and members of the general public would be less than 0.17 and 0.37 mrem/yr, respectively, from airborne emission of UO_2F_2. The dose for the general public MEI would be greater than that for the noninvolved worker MEI because of the close proximity from the assumed emissions point to the site boundary. Potential radiation exposure from the use of contaminated groundwater would result in a dose of less than 0.081 mrem/yr at the end of this period.

Long-term radiation exposure after the year 2028 from the use of contaminated groundwater would result in a maximal dose of 0.64 mrem/yr.

D.4.1.2 Chemical Impacts

Chemical impacts associated with continued cylinder storage could result primarily from exposure to uranium compounds and HF released from hypothetical cylinder breaches. Estimated impacts for each of the three storage sites are given in Table D.25. The highest hazard quotients result when the use of contaminated groundwater is considered in addition to exposures through inhalation, soil ingestion, and surface water ingestion (i.e., maximum hazard quotient of 0.17 at the Paducah site). Adverse health effects would not be expected from exposure to chemical contaminants associated with continued cylinder storage (that is, the estimated hazard indices would all be less than the threshold value of 1).

D.4.2 Human Health — Accident Conditions

The assessment of impacts conducted for potential accidents associated with continued cylinder storage under the action alternatives was similar to that for the no action alternative (Section D.2.2) in that the same accidents were considered and the consequences of those accidents would be the same. However, because the duration of continued cylinder storage under the action alternatives is 11 years shorter than that assessed for the no action alternative (i.e., 30 years assumed for the action alternatives compared with 41 years assumed for the no action alternative), the risk of these accidents occurring would therefore be somewhat lower under the action alternatives.

TABLE D.25 Chemical Impacts to Human Health from Continued Cylinder Storage under Normal Operations for the Action Alternatives

	Impacts to Receptor			
	Noninvolved Workers[a]		General Public[b]	
Site/Time Period	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)
Paducah site 1999-2028	1.6×10^{-3}	–	5.2×10^{-3} (9.0×10^{-3})	–
Long-term impacts[e]	NA[f]	–	0.02 – 0.17	–
Portsmouth site 1999-2028	3.9×10^{-5}	–	3.0×10^{-3} (6.4×10^{-4})	–
Long-term impacts[e]	NA	–	0.003 – 0.03	–
K-25 site 1999-2028	1.1×10^{-3}	–	6.5×10^{-2} (1.1×10^{-2})	–
Long-term impacts[e]	NA	–	0.01 – 0.08	–

[a] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. The MEI for the noninvolved worker was assumed to be at the on-site (outside storage yards) location that would yield the largest exposure. Exposures would result from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders; the exposure pathways considered included inhalation and incidental ingestion of soil.

[b] The MEI for the general public was assumed to be located off-site at the point that would yield the largest exposure. Results reported are the maximum values for the time period considered and would result from exposure via inhalation; ingestion of soil (resulting from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders); and drinking surface water (consequence of the discharge of contaminated runoff water to a surface water body). Potential impacts during the storage period 1999-2028 (values within parentheses) were also evaluated from the use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

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

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

[e] Long-term impacts would result from using contaminated groundwater.

[f] NA = not applicable; workers were assumed not to ingest groundwater.

D.4.2.1 Radiological Impacts

The accidents that might be associated with continued cylinder storage under the action alternatives are identical to those addressed under the no action alternative. See Section D.2.2.1 for the discussion of potential human health impacts associated with radiological exposures from accidental releases.

D.4.2.2 Chemical Impacts

The accidents that might be associated with continued cylinder storage under the action alternatives are identical to those addressed under the no action alternative. See Section D.2.2.2 for the discussion of potential human health impacts associated with chemical exposures from accidental releases.

D.4.2.3 Physical Hazards

The activities considered in calculating the physical hazards associated with continued cylinder storage were routine cylinder inspections, ultrasonic inspections, valve monitoring and maintenance activities, cylinder relocations, cylinder yard construction or reconstruction, cylinder painting, and patching and content transfers of breached cylinders. The annual labor requirements and the corresponding fatality and injury risks to all workers for these activities were estimated to be less than 1 (0.07) for the total three-site fatality risk and about 90 injuries for the total three-site injury risk (see Table D.26).

D.4.3 Air Quality

The assessment of air quality impacts from construction, relocating cylinders, and painting cylinders conducted for the no action alternative would also be applicable for the action alternatives because the assessment was based on maximum annual impacts (i.e., the same construction activities were assumed, as well as the same levels of relocating and painting cylinders during the initial years of continued storage). Potential impacts on air quality from these activities are discussed in Section D.2.3.

The estimated HF emissions for the action alternatives would differ from those for the no action alternative because different numbers of breached cylinders were assumed (see Appendix B). The numbers of hypothetical breaches and estimated resulting HF concentrations at the three current storage sites are given in Table D.27. The estimated 0.27 $\mu g/m^3$ maximum 24-hour average HF concentration for the Paducah site is considerably below the Kentucky primary annual standard for HF of 400 $\mu g/m^3$ (0.5 ppm). The estimated 2.7 $\mu g/m^3$ maximum 24-hour average HF concentration for the K-25 site is below the Tennessee 24-hour average standard of 2.9 $\mu g/m^3$.

TABLE D.26 Estimated Impacts to Human Health from Physical Hazards under Continued Cylinder Storage for the Action Alternatives[a,b]

Impacts to All Workers (Involved and Noninvolved)[c]							
Fatality Incidence				*Injury Incidence*			
Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites	Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites
0.03	0.02	0.02	0.07	41	26	23	90

[a] Potential impacts are based on continued storage activities, which would include routine inspections, ultrasonic inspections, valve monitoring and maintenance, cylinder relocations, cylinder yard construction and reconstruction, cylinder painting, and patching and content transfers for breached cylinders for the time period 1999-2028.

[b] Risk estimates include reconstruction of L-, M-, N-, and P-yards at Paducah and construction of a new yard at K-25.

[c] Injury and fatality rates used in the calculations were taken from National Safety Council (1995).

TABLE D.27 Estimated Number of Breached Cylinders, Maximum HF Emissions, and Average Maximum HF Concentrations at the Existing Storage Sites for the Action Alternatives

Site	Maximum Number of Breaches Starting in a Single Year	Maximum Total Number of Active Breaches in a Single Year	Maximum HF Concentration (μg/m³): 24-Hour Average	Maximum HF Concentration (μg/m³): Annual Average
Paducah	4	16	0.27	0.03
Portsmouth	1	4	0.14	0.015
K-25	3	8	2.7	0.34

D.4.4 Water and Soil

D.4.4.1 Surface Water

The estimated numbers of cylinder breaches assumed to occur during continued cylinder storage for the action alternatives are given in Appendix B. These estimates were used to calculate potential impacts to surface water quality. Each breached cylinder was assumed to release a maximum of 4 lb (1.8 kg) of uranium over 4 years; additional details on the methodology used to evaluate the impacts are given in Appendix C and Tomasko (1997b).

The estimated maximum uranium concentrations in runoff water leaving the yards would be about 121, 25, and 130 µg/L (31, 6, and 34 pCi/L) for the Paducah, Portsmouth, and K-25 sites, respectively. These concentrations would occur in about the year 2018. After leaving the yards, the contaminated runoff was assumed to flow without loss to the nearest surface water, where it would mix and be diluted. For average flow conditions, the dilution would be large enough that the maximum concentrations would be less than 2 µg/L (0.5 pCi/L) for all three sites (see Table D.28). This concentration is less than the EPA proposed drinking water MCL for uranium of 20 µg/L, used here for comparison. The contaminated water would then mix with water in the Ohio River, Scioto River, or Clinch River, which would result in even greater dilution. Because of this mixing, impacts to the major rivers would not be measurable.

TABLE D.28 Maximum Uranium Concentrations in Surface Waters for Continued Cylinder Storage under the Action Alternatives

Site	Receiving Water	Dilution Factor	Maximum Concentration (µg/L)
Paducah	Big Bayou Creek	124	1.7
	Ohio River	43,600	0.00002
Portsmouth	Little Beaver Creek	26	1
	Scioto River	2,240	0.0005
K-25	Poplar Creek	2,550	0.05
	Clinch River	94	0.0005

D.4.4.2 Groundwater

Methods for estimating groundwater impacts were the same as those used for the no action alternative (Section D.2.4.2); however, a larger number of cylinder breaches was assumed to occur. Conservative estimates of the concentrations of uranium in groundwater were obtained by assuming the surface value to be equal to the maximum concentration in water leaving each yard during a time interval of approximately 20 years; this time interval corresponds to the time over which the concentration in surface water would be higher than half of its maximum value.

At the end of the time period considered for the action alternatives (1999-2028), the concentration of uranium in groundwater directly below the edge of the surface contamination at the Paducah, Portsmouth, and K-25 sites is estimated to be about 1.1, 0.09, and 1.3 µg/L (0.3, 0.02, and 0.3 pCi/L), respectively, for a retardation factor of 5 (Table D.29) (Tomasko 1997b). These concentrations are less than the proposed EPA drinking water MCL for uranium of 20 µg/L, used here for comparison (EPA 1996).

Maximum concentrations of about 20, 4, and 9 µg/L (5, 1, and 3 pCi/L) would occur between the years 2070 and 2080 at Paducah, Portsmouth, and K-25, respectively, assuming a retardation factor of 5. The maximum concentration would only equal the EPA proposed drinking water guideline at Paducah; this guideline is not directly applicable because the groundwater directly at the boundary of the nearest surface water is unlikely to be used as a drinking water source. For a retardation factor of 50 (relatively immobile uranium transport), maximum concentrations would be about 10 times less. These concentrations would occur between the years 2500 and 2700.

Assuming a retardation factor of 5 and a distance of 1,000 ft (300 m) from the edge of the source area, the maximum concentration of uranium would range from about 9 µg/L (3 pCi/L at the K-25 site to 16 µg/L (4 pCi/L) at the Paducah site. For less mobile conditions (retardation of 50), the maximum concentrations would be about 10 times less.

D.4.4.3 Soil

Maximum uranium concentrations in soil for a distribution coefficient of 50 (relatively high sorption capacity) would range from 1.2 µg/g for the Portsmouth site to 6.5 µg/g for the K-25 site. If the soil had a lower sorption capacity (distribution coefficient of 5), the soil concentrations would be 10 times lower. These maximum soil concentrations associated with continued cylinder storage under the action alternatives are much lower than the recommended EPA guideline levels of 230 µg/g for residential soil or 1,000 µg/g for industrial soil (EPA 1995).

TABLE D.29 Groundwater Concentrations for Continued Cylinder Storage for Two Soil Characteristics under the Action Alternatives[a]

	X = 0			X = 1,000 ft		
	Concentration		Time to Maximum Concentration	Concentration		Time to Maximum Concentration
Site/Parameter	pCi/L	μg/L		pCi/L	μg/L	
Retardation Factor = 5						
Paducah						
Concentration at 30 years	0.28	1.1				
Maximum concentration	5.2	20	> 70 years	4.0	16	> 70 years
Portsmouth						
Concentration at 30 years	0.02	0.09				
Maximum concentration	0.8	3.5	> 70 years	0.7	2.8	> 70 years
K-25						
Concentration at 30 years	0.33	1.3				
Maximum concentration	2.5	9.4	> 70 years	2.0	7.7	> 70 years
Retardation Factor = 50						
Paducah						
Maximum concentration	0.5	2.1	> 500 years	0.4	1.6	> 500 years
Portsmouth						
Maximum concentration	0.08	0.4	> 500 years	0.07	0.3	> 500 years
K-25						
Maximum concentration	0.3	1.1	> 500 years	0.2	0.8	> 500 years

[a] Retardation factors describe how readily a contaminant such as uranium moves through the soil in groundwater. A retardation factor of 5 represents a case in which the uranium moves relatively rapidly in the soil; a retardation factor of 50 represents a case in which uranium moves slowly.

D.4.5 Socioeconomics

The methods used to assess socioeconomic impacts of continued cylinder storage for the action alternatives were the same as those used for the no action alternative (Section D.2.5). Impacts are presented in Table D.30. Construction impacts would be identical to those estimated for the no action alternative because all construction would take place during the time period 1999-2008, when identical activities are assumed. For K-25, the estimated impacts from operations under the action alternatives are slightly higher than those estimated for the no action alternative, primarily because of the increased number of cylinder breaches assumed, which would require increased levels of activities for repairs, thus leading to increased employment. Under the action alternatives,

TABLE D.30 Potential Socioeconomic Impacts of Continued Cylinder Storage under the Action Alternatives

	Paducah Site		Portsmouth Site		K-25 Site	
Parameter	Impacts from Construction[a]	Impacts from Operations[b]	Impacts from Construction[c]	Impacts from Operations[b]	Impacts from Construction[a]	Impacts from Operations[b]
Economic activity in the ROI						
Direct jobs	20	60	–	20	10	40
Indirect jobs	60	30	–	10	50	70
Total jobs	80	90	–	30	60	110
Income ($ million)						
Direct income	1.0	1.7	–	0.5	0.4	3.8
Total income	2.0	2.2	–	0.6	1.5	5.1
Population in-migration into the ROI	70	30	–	10	20	30
Housing demand						
Number of units in the ROI	20	10	–	0	10	10
Public finances						
Change in ROI fiscal balance (%)	0.0	0.0	–	0.0	0.0	0.0

[a] Impacts for peak construction year. Construction activities were assumed to occur over 4 years (1999-2002) at the Paducah site and over 1 year (1999) at the K-25 site.

[b] Impacts for peak year of operations. Duration of operations was assumed to be 30 years (1999-2028).

[c] No construction activities are planned for continued cylinder storage at the Portsmouth site.

continued storage activities would still have a negligible impact on socioeconomic conditions in the ROIs surrounding the three sites.

D.4.6 Ecology

For continued cylinder storage under the action alternatives, the maximum annual average HF concentrations would be 0.009 $\mu g/m^3$, 0.015 $\mu g/m^3$, and 0.081 $\mu g/m^3$ for the Paducah, Portsmouth, and K-25 sites, respectively (Section D.4.3). Resulting impacts to biota would be expected to be negligible. Contamination of soils near the storage yards by surface runoff could result in maximum uranium concentrations of 6.1 µg/g at the Paducah site, 1.2 µg/g at the Portsmouth site, and 6.5 µg/g at the K-25 site (Section D.4.4). The predicted concentrations for the Paducah and K-25 sites are approximately the same as the lowest uranium concentration reported to produce toxic effects in plants (5 µg/kg). The extent of vegetation affected would be restricted to the area of surface runoff from the yards. Therefore, impacts to vegetation would be expected to be negligible to low. Surface runoff from the storage yards would have a maximum uranium concentration of 121 µg/L (31 pCi/L) at the Paducah site, 25 µg/L (6 pCi/L) at the Portsmouth site, and 130 µg/L (34 pCi/L) at the K-25 site (Section D.4.4). Resulting impacts to maximally exposed organisms in the nearest receiving surface water body at each site would be expected to be negligible. Uranium concentrations in groundwater would be considerably less and resulting impacts to aquatic biota would be negligible.

Uranium concentrations in groundwater following the cylinder removal period would be very low, and long-term impacts to aquatic biota would not be expected. Contaminants associated with cylinder storage would not occur in other environmental media following the cylinder removal period.

D.4.7 Waste Management

As for the no action alternative, the principal wastes that are expected to be generated during continued cylinder storage are uranium-contaminated scrap metal from breached cylinders and failed valves, assumed to be LLW, and solid process residue from cylinder painting, assumed to be LLMW. The amounts of these waste types estimated to be generated for continued cylinder storage under the action alternatives is given in Table D.31. The annual amount of LLW generated would be less than 2% of site LLW generation for all three sites. The maximum annual amount of LLW generated during continued cylinder storage at all three sites would represent less than 1% of the annual DOE LLW generation.

For the Portsmouth and K-25 sites, the annual amount of LLMW generation would be less than 1% of site LLMW generation. However, for the Paducah site, the annual amount of LLMW generated during the initial years of evaluation, when painting of the entire inventory was assumed

TABLE D.31 Waste Generated during Continued Cylinder Storage under the Action Alternatives

	Waste (m^3)	
Site	LLW[a]	LLMW[b]
Paducah	792	440
Portsmouth	350	204
K-25	206	45
Total (1999-2028)	1,348	689

[a] Contaminated scrap metal from empty cylinders.

[b] Inorganic process residues from cylinder painting.

to occur (23 m^3/yr), would represent about 20% of the site's total annual LLMW load, a moderate impact on site waste management capabilities. The input of LLMW from continued storage would represent less than 1% of the total nationwide LLMW load.

Overall, the waste input resulting from the continued storage of cylinders under the action alternatives would have negligible impacts on waste management capabilities at the Portsmouth and K-25 sites. Impacts from disposal of LLMW could have moderate impacts at the Paducah site. Impacts on national waste management capabilities would be negligible.

D.4.8 Resource Requirements

Resource requirements for continued cylinder storage under the action alternatives are summarized in Table D.32. The resource requirements for construction would be identical to those for the no action alternative. The upper end of the range of annual requirements shown in Table D.32 generally corresponds to the upper end of the range estimated for the no action alternative; these requirements represent the early years of continued cylinder storage when some construction activities are planned. The lower end of the range of annual resource requirements is lower than the lower values for the no action alternative because maintenance of the decreasing cylinder inventory would require fewer resources.

The total quantities of commonly used construction materials needed for continued storage under the action alternatives are expected to be small compared with local sources. No strategic and critical materials are projected to be consumed for either construction or operations. Small amounts

TABLE D.32 Resource Requirements of Construction and Operations for Continued Cylinder Storage under the Action Alternatives

		Consumption during 1999-2028		
Materials/Resource	Unit	Paducah Site	Portsmouth Site	K-25 Site
Construction				
Solids				
Concrete	yd^3	20,000	0	8,000
Construction aggregate	yd^3	29,000	0	12,000
Special coatings	yd^2	90,000	0	36,000
Liquids				
Gasoline	gal	3,100	0	1,300
Diesel fuel	gal	18,000	0	7,300
Operations[a]				
Solids				
55-gal drums	each	53 – 109	26 – 50	10 – 18
Cylinder valves (1-in.)	each	4 – 9	2 – 4	1 – 2
Liquids				
Gasoline	gal/yr	2,000 – 4,500	810 – 1,600	450 – 1,000
Diesel fuel	gal/yr	4,300 – 13,600	2,100 – 4,100	800 – 2,600
Zinc-based paint	gal/yr	2,900 – 6,000	1,400 – 2,700	470 – 1,000

[a] Values reported as ranges generally correspond to varying resource requirements during years for which construction activities are planned.

of diesel fuel and gasoline are projected to be used. The required material resources during operations would appear to be readily available.

D.4.9 Land Use

Construction activities assumed for continued storage under the action alternatives are identical to those assumed for the no action alternative. Therefore, potential land-use impacts would be the same as those discussed in Section D.2.9.

D.4.10 Cultural Resources

Potential impacts to cultural resources under the action alternatives would be identical to those discussed in Section D.2.10.

D.4.11 Environmental Justice

Because no screening criteria limits for radiological and chemical sources under normal operations were exceeded under the action alternatives, no disproportionate impacts to minority and low-income populations would be associated with normal operations for continued cylinder storage. The assessment of impacts for potential accidents associated with continued cylinder storage under the action alternatives is similar to that for the no action alternative (Section D.2.11) in that the same accidents were considered and the consequences of those accidents would be the same. However, because the duration of continued cylinder storage under the action alternatives is 11 years shorter than that assessed for the no action alternative (i.e., 30 years assumed for the action alternatives compared with 41 years assumed for the no action alternative), the risk of these accidents occurring is somewhat lower. However, the conclusion that no disproportionate impacts would be associated with continued cylinder storage under the no action alternative is still applicable for the action alternatives because risks are lower for these alternatives.

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