# 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 or generic environmental settings for assessment purposes. The environmental characteristics of the 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.

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[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:<br>*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.<br>*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.

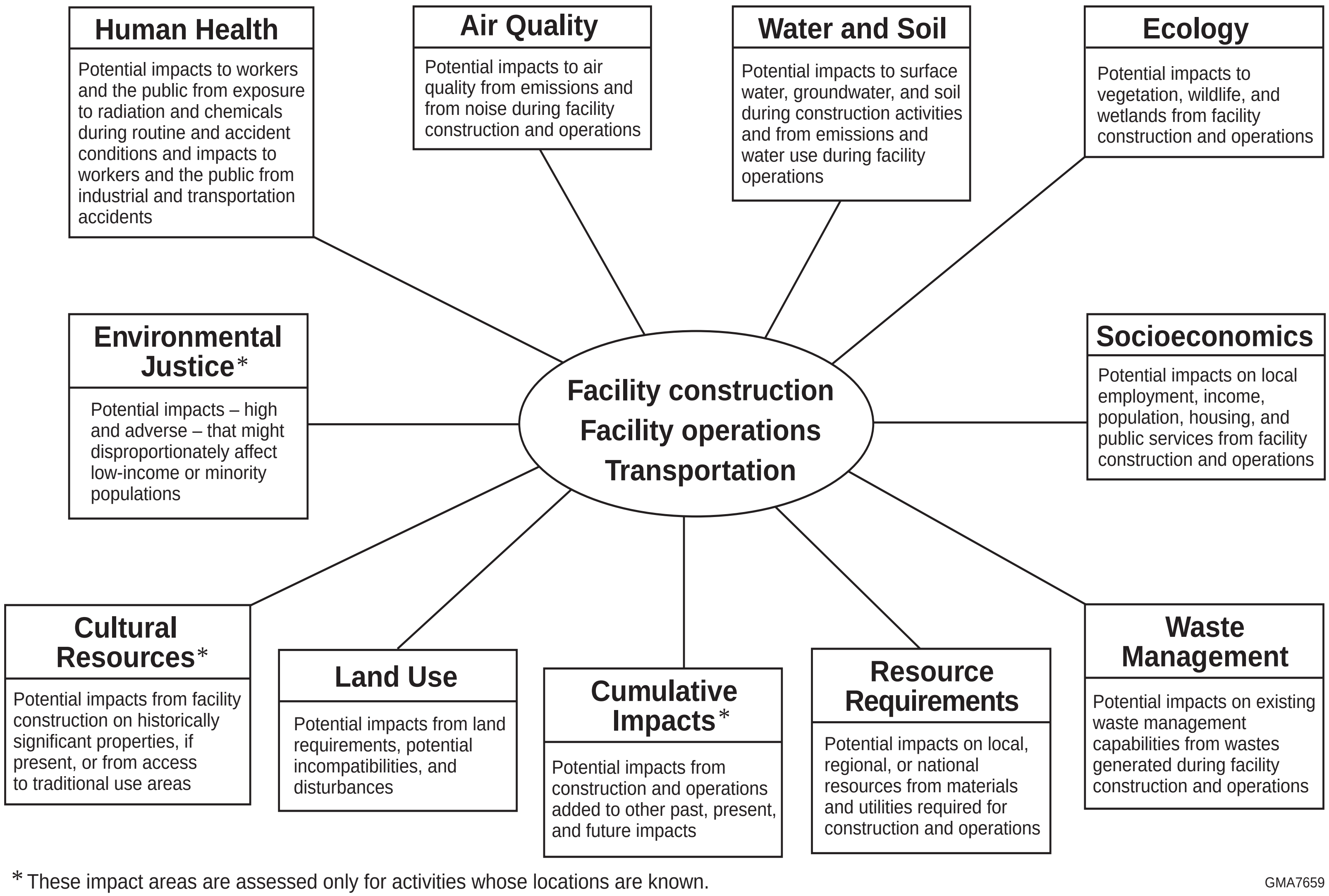


**FIGURE 4.1 Areas of Potential Impact Evaluated in the PEIS for Each Alternative**

## 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 juris-dictional revenues and expenditures. | Between 1% and 5% increase in local jurisdictional revenues and expenditures. | More than 5% increase in local juris-dictional 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.)**

| | General Criteria Used to Define Descriptor Term | | |
|---|---|---|---|
| Area of Impact | 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 ÷ 70 ≈ 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 ÷ 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 $1 \times 10^{-2}$/yr to $1 \times 10^{-4}$/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 $1 \times 10^{-4}$/yr to $1 \times 10^{-6}$/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.