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United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-1910, Vol. 1

Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities

Chapters 1 through 4

Final Report

Office of Federal and State Materials and
Environmental Management Programs

Wyoming Department of Environmental Quality
Land Quality Division

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ABSTRACT

The Atomic Energy Act of 1954 and the Uranium Mill Tailings Radiation Control Act of 1978 authorize the U.S. Nuclear Regulatory Commission (NRC) to issue licenses for the possession and use of source material and byproduct material. These statutes require NRC to license facilities that meet NRC regulatory requirements that were developed to protect public health and safety from radiological hazards. *In-situ* leach (ISL) uranium recovery facilities must meet NRC regulatory requirements in order to obtain a source material license to operate.

Under NRC's environmental protection regulations in the Code of Federal Regulations, Title 10, Part 51, which implement the National Environmental Policy Act (NEPA), issuance of a license to possess and use source material for uranium milling requires an environmental impact statement (EIS) or a supplement to an EIS. NRC has prepared a generic environmental impact statement (GEIS) to help fulfill this requirement. The GEIS assesses the potential environmental impacts associated with the construction, operation, aquifer restoration, and decommissioning of an ISL uranium recovery facility in four specified regions in the western United States. The intent of the GEIS is to determine which impacts would be essentially the same for all ISL facilities and which ones would result in varying levels of impacts for different facilities, thus requiring further site-specific information to determine the potential impacts. As such, the GEIS provides a starting point for NRC's NEPA analyses for site-specific license applications for new ISL facilities, as well as for applications to amend or renew existing ISL licenses.

NRC developed this GEIS using (1) knowledge gained during the past 30 years licensing and regulating ISL facilities, (2) the active participation of the State of Wyoming Department of Environmental Quality as a cooperating agency, and (3) public comments received during the preparation of the GEIS. NRC's licensing experience indicates that the technology used for ISL uranium recovery is relatively standardized throughout the industry and therefore appropriate for a programmatic evaluation in a GEIS.

Based on discussions between uranium recovery companies and the NRC staff, future ISL facilities could be located in portions of Wyoming, Nebraska, South Dakota, and New Mexico. NRC is the licensing authority for ISL facilities in these states.

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EXECUTIVE SUMMARY

BACKGROUND

The Atomic Energy Act of 1954 and the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) authorize the U.S. Nuclear Regulatory Commission (NRC) to issue licenses for the possession and use of source material and byproduct material. The statutes require NRC to license facilities that meet NRC regulatory requirements that were developed to protect public health and safety from radiological hazards. *In-situ* leach (ISL) uranium recovery facilities must m3eet NRC regulatory requirements in order to obtain this license to operate.

NRC designed the licensing process to assure the safe operation of ISL facilities. In addition to information for a safety evaluation review, license applicants must submit an environmental report as part of their license application. Under the NRC's environmental protection regulations in the Code of Federal Regulations, Title 10, Part 51 (10 CFR Part 51), which implement the National Environmental Policy Act (NEPA), issuance of a license to possess and use source material for uranium milling requires an environmental impact statement (EIS) or a supplement to an EIS.

> **Generic Environmental Impact Statement (GEIS)**
>
> A GEIS is an environmental impact statement that assesses the scope of the environmental effects that would be associated with an action (such as issuing a license for an ISL facility) at numerous sites. The Commission directed the NRC staff to prepare the GEIS to cover as many of the potential uranium recovery sites as possible.
>
> **Supplemental Environmental Impact Statement (SEIS)**
>
> A supplemental EIS updates or supplements an existing EIS (such as the GEIS). The Commission directed the NRC staff to issue site-specific supplements to the GEIS for each new license application.

NRC prepared the Generic Environmental Impact Statement for *In-Situ* Leach Uranium Milling Facilities (GEIS) to help fulfill this requirement. The GEIS was prepared to assess the potential environmental impacts associated with the construction, operation, aquifer restoration, and decommissioning of an ISL facility in four specified geographic areas. The intent of the GEIS is to determine which impacts would be essentially the same for all ISL facilities and which ones would result in varying levels of impacts for different facilities, thus requiring further site-specific information to determine the potential impacts. As such, the GEIS provides a starting point for NRC's NEPA analyses on site-specific license applications for new ISL facilities, as well as for applications to amend or renew existing ISL licenses.

PURPOSE AND NEED

Commercial uranium recovery companies have approached NRC with plans to submit a number of license applications for new uranium recovery facilities and for the restart or expansion of existing facilities in the next several years. The large majority of these potential applications would involve use of the ISL process. The companies have indicated that these new, restarted, and expanded ISL facilities would be located in Wyoming, South Dakota, Nebraska, and New Mexico.

NRC is the regulatory authority responsible for issuing a source material license for an ISL facility in those four states. 10 CFR Part 51 regulations require evaluating the environmental impacts of the ISL facility as part of the licensing process. Recognizing that the technology for ISL uranium milling is relatively standardized, that the applications may be submitted over a relatively short period of time, and that the potential ISL facilities would be located in relatively

discrete regions in the western United States, NRC decided to prepare a GEIS to avoid unnecessary duplicative efforts and to identify environmental issues of concern to focus on in site-specific environmental reviews. In this way, NRC could increase the efficiency and consistency in its site-specific environmental review of license applications for ISL facilities and so provide an option for applicants to use and licensees to continue to use the ISL process for uranium recovery.

THE PROPOSED FEDERAL ACTION AND ALTERNATIVES

In states where NRC is the regulatory authority over the licensing of uranium milling (including the ISL process), NRC has a statutory obligation to assess each site-specific license application to ensure it complies with NRC regulations before issuing a license. The proposed federal action is to grant an application to obtain, renew, or amend a source material license for an ISL facility.

Under NRC's environmental protection regulations at 10 CFR 51.20(b)(8), issuing a license to possess and use source material to a uranium milling facility is identified as a major federal action that requires the preparation of an EIS or a supplement to an EIS. NRC will prepare a SEIS for new ISL facility license applications. NRC will prepare an EA, SEIS or EIS for applications to amend or renew an existing ISL facility license.

<u>**The Proposed Federal Action**</u>

To grant applications to obtain, renew, or amend source material licenses for an ISL facility.

<u>**Purpose for the Proposed Federal Action**</u>

To provide an option for an applicant to use or a licensee to continue to use ISL technology for uranium recovery

The environmental review requirements for a material license are in 10 CFR Part 51. NRC's public health and safety requirements for ISL facilities are found in 10 CFR Parts 20 and 40. Parts 20, 40, and 51 require applicants to provide NRC with sufficient information to evaluate the impacts to public health and safety and the environment during the life-cycle of the ISL facility. NRC then prepares safety and environmental reviews that are used by NRC officials to decide whether to grant the source material license.

In reviewing an ISL license application, NRC will use the GEIS as starting point for its site-specific environmental reviews. NRC will evaluate site-specific data and information to determine whether the applicant's proposed activities and the site characteristics are consistent with those evaluated in the GEIS. NRC will then determine which sections of the GEIS can be incorporated by reference and which impact conclusions can be adopted in the site-specific environmental review, and whether additional data or analysis is needed to determine the environmental impacts to a specific resource area. Additionally, the GEIS provides guidance in the evaluation for certain impact analyses (e.g., cumulative impacts, environmental justice) for which the GEIS did not make impact conclusions. No decision on whether to license an ISL facility will be made based on the GEIS alone. The licensing decision will be based, in part, on a site-specific environmental analysis that makes use of the GEIS.

Uranium milling techniques are designed to recover the uranium from uranium-bearing ores. Various physical and chemical processes may be used, and selection of the uranium milling technique depends on the physical and chemical characteristics of the ore deposit and the attendant cost considerations. Generally, the ISL process is used to recover uranium from low-grade ores or deeper deposits that are not economically recoverable by conventional mining and milling techniques. In the ISL process, a leaching agent, such as oxygen with sodium carbonate, is added to native groundwater and injected through wells into the subsurface ore body to mobilize the uranium. The leach solution containing the mobilized uranium is pumped from there to the surface processing plant, and then ion exchange separates the uranium from the solution. After additional purification and drying, the resultant product, a mixture of uranium oxides also known as "yellowcake," is placed in 55-gallon drums prior to shipment offsite for further processing.

A range of alternatives was evaluated for inclusion in the GEIS. As defined in the GEIS, the proposed federal action is NRC's determination to grant an application to obtain, renew, or amend a source material license for an ISL facility. Under the no-action alternative, NRC would deny the applicant's or licensee's request. As a result, the new license applicant may choose to resubmit the application to use an alternate uranium recovery method or decide to obtain the yellowcake from other sources. A licensee whose renewal application is denied would have to commence shutting down operations in a timely manner. Denials of license amendments would require the licensee to continue operating under its previously approved license conditions.

Alternative methods for milling uranium were considered as possible alternatives to the ISL process. As stated previously, not all uranium deposits are suitable for ISL extraction. For example, if the uranium mineralization is above the saturated zone (i.e., all of the pore spaces in the ore-bearing rock are not filled with water), ISL techniques may not be appropriate. Likewise, if the ore is not located in a porous and permeable rock unit, it will not be accessible to the leach solution used in the ISL process. Because ISL techniques may not be appropriate in these circumstances, conventional mining (underground or open-pit/surface mining) and milling techniques (conventional milling and heap leaching) are viable alternative technologies.

Inasmuch as the suitability and practicality of using alternative milling methodologies depends on site-specific conditions, a generic discussion of alternative milling methodologies is not appropriate. Accordingly, this GEIS does not contain a detailed analysis of alternative milling methodologies. A detailed analysis of alternative milling methodologies that can be applied at a specific site will be addressed in NRC's site-specific environmental review for individual ISL license applications.

ANALYTICAL APPROACH

The GEIS serves to increase efficiency and eliminate repetitive discussions in NRC's environmental review process by identifying and evaluating environmental impacts that are generic and common to ISL uranium recovery facilities. Information from the GEIS can be summarized and incorporated by reference into the subsequent site-specific environmental review documents. The GEIS also identifies resource areas that need site-specific information to more fully determine the environmental impact to particular resource areas. The site-specific environmental impact analysis also will include any new or significant information necessary to evaluate the ISL facility license application.

For the GEIS, NRC identified the potential environmental impacts associated with the ISL process and the resource areas that could be affected. The general methodology for doing so was to (1) describe the ISL process activity or activities that could affect the resource, (2) identify the resource(s) that can be affected, (3) evaluate past licensing actions and associated environmental review documents and other available information, (4) assess the nature and magnitude of the potential environmental impacts to the resource(s), (5) characterize the significance of the potential impacts, and (6) identify site conditions and mitigation measures that may affect the significance. For some types of impacts analyses (e.g., cumulative impacts, environmental justice evaluations), NRC recognized the difficulty in making determinations in the GEIS, given the location-specific nature of these analyses. For these categories, NRC collected information and conducted initial evaluations, which are documented in the GEIS. The purpose of this information gathering and initial evaluation is intended to provide background data and guidance for the site-specific analyses for these types of impact evaluations.

NRC developed this GEIS based on its experience in licensing and regulating ISL facilities gained during the past 30 years. In the GEIS, NRC does not consider specific facilities, but rather provides an assessment of potential environmental impacts associated with ISL facilities that might be located

in four regions of the western United States. These regions are used as a framework for discussions in this GEIS and were identified based on several considerations, including

- Past and existing uranium milling sites are located within States where NRC has regulatory authority over uranium recovery;
- Potential new sites are identified based on NRC's understanding of where the uranium recovery industry has plans to develop uranium deposits using ISL technology; and
- Locations of previously identified uranium deposits within portions of Wyoming, Nebraska, South Dakota, and New Mexico.

Using these criteria, four geographic regions were identified (Figure ES–1). For the purpose of this GEIS, these regions are

- Wyoming West Uranium Milling Region
- Wyoming East Uranium Milling Region
- Nebraska-South Dakota-Wyoming Uranium Milling Region
- Northwestern New Mexico Uranium Milling Region

The foundation of the environmental impact assessment in the GEIS is based on (1) the historical operations of NRC-licensed ISL facilities and (2) the affected environment in each of the four regions. The structure of the GEIS is presented in Figure ES–2.

Chapter 2 of the GEIS provides a description of the ISL process, addressing construction, operation, aquifer restoration, and decommissioning of an ISL facility. This section also discusses financial assurance, whereby the licensee or applicant establishes a bond or other financial mechanism prior to operations to ensure that sufficient funds are available to complete aquifer restoration, decommissioning, and reclamation activities.

Chapter 3 of the GEIS describes the affected environment in each uranium milling region using the environmental resource areas and topics identified through public scoping comments on the GEIS and from NRC guidance to its staff in NUREG–1748, "Environmental Review Guidance for Licensing Actions Associated With NMSS Programs," issued in 2003.

Chapter 4 of the GEIS provides an evaluation of the potential environmental impacts of constructing, operating, aquifer restoration, and decommissioning at an ISL facility in each of the four uranium milling regions. In essence, this involves placing an ISL facility with the characteristics described in Chapter 2 of the GEIS within each of the four regional areas described in Chapter 3 and describing and evaluating the potential impacts in each region separately. The potential environmental impacts are evaluated for the different stages in the ISL process: construction, operation, aquifer restoration, and decommissioning. Impacts are examined for the resource areas identified in the description of the affected environment. These resource areas are

- Land use
- Transportation
- Geology and soils
- Water resources
- Ecology
- Air quality
- Noise
- Historical and cultural resources
- Visual and scenic resources
- Socioeconomic
- Public and occupational health

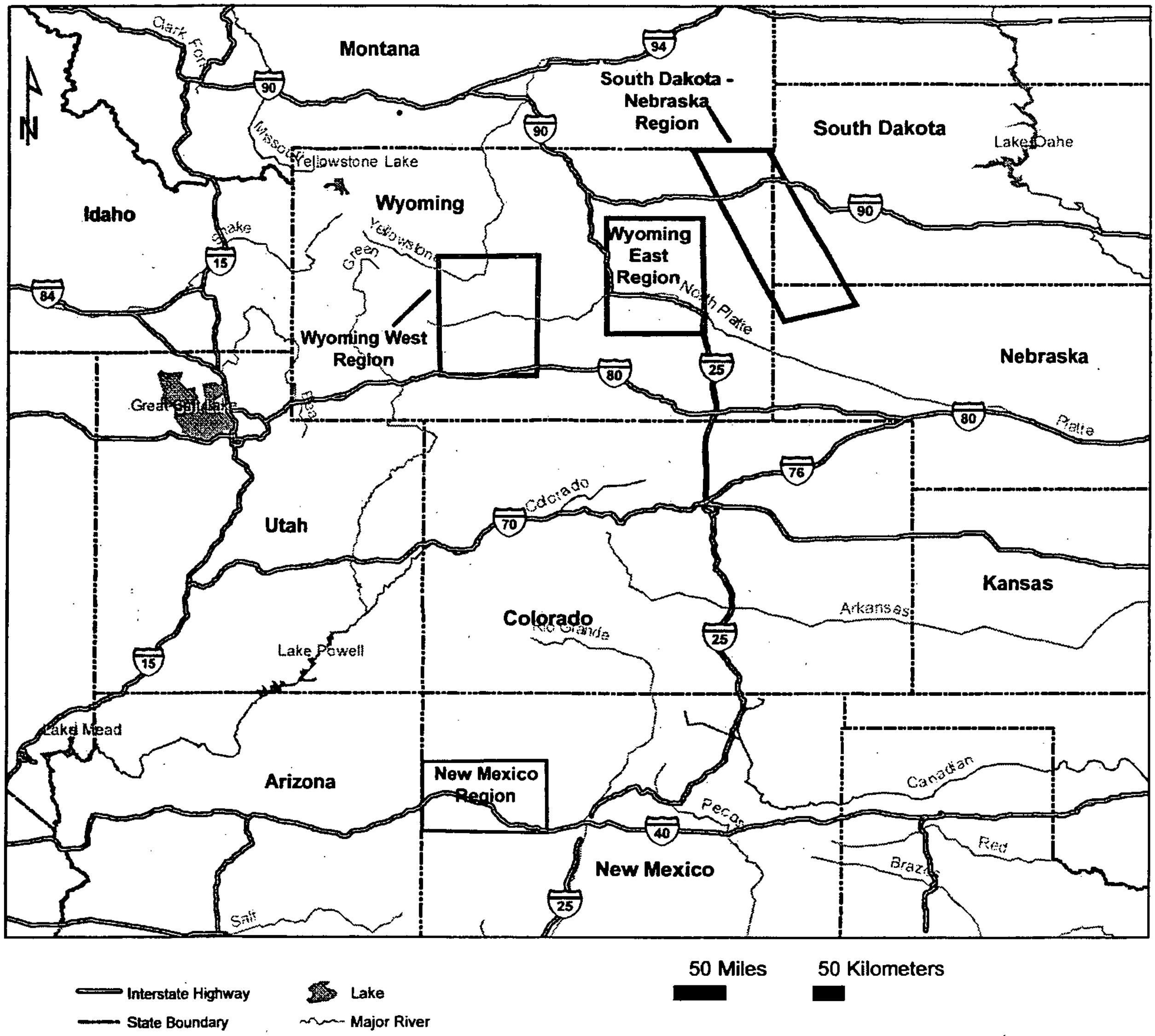

Figure ES–1. Location of Four Geographic Regions Used as a Framework for the Analyses Presented in This GEIS

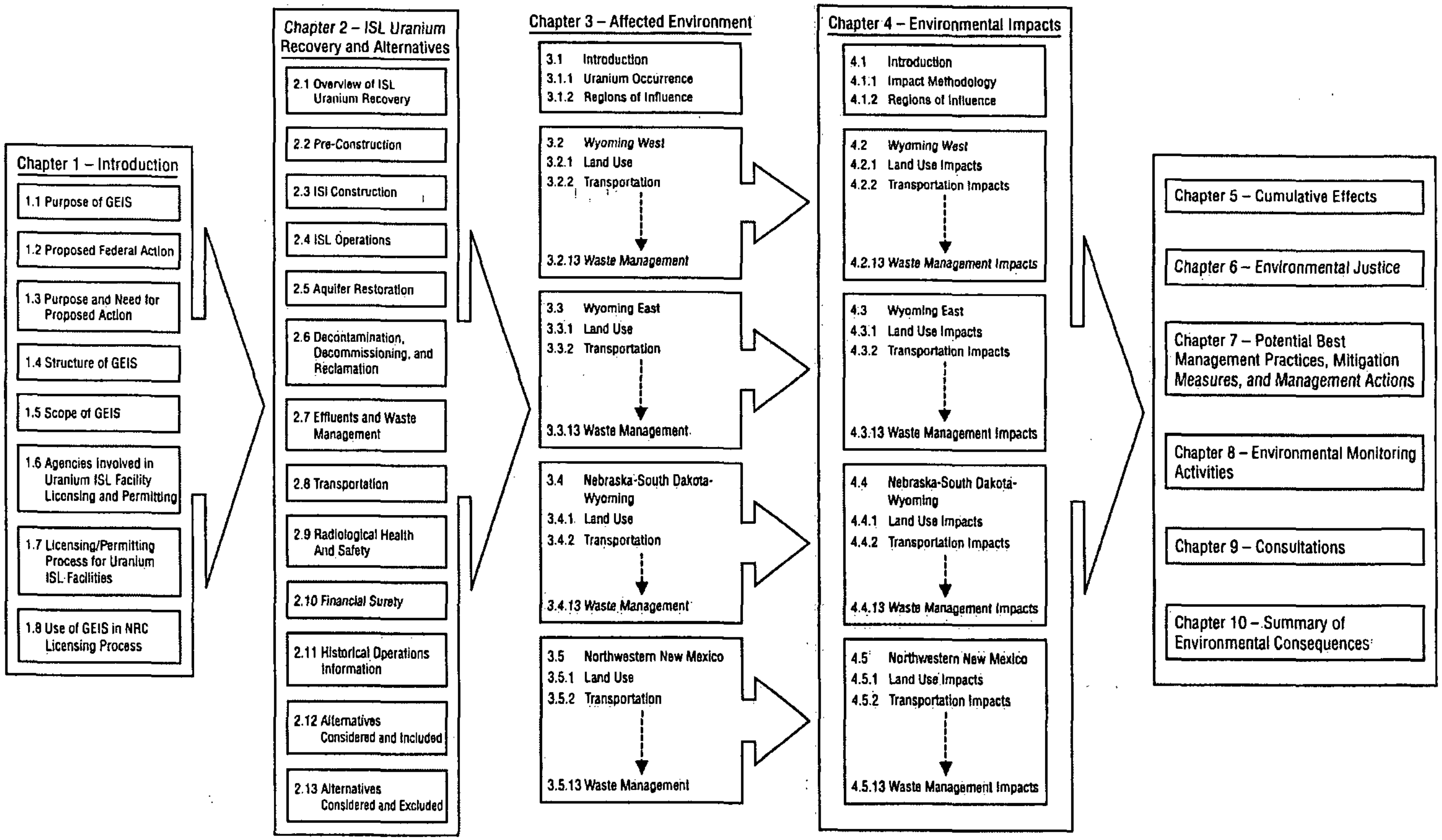

Figure ES–2. Structure of This GEIS

NRC identified a number of other issues that helped in the evaluation of the potential environmental impacts of an ISL facility. These issues include

- **Applicable Statutes, Regulations, and Agencies**. Various statutes, regulations, and implementing agencies at the federal, state, tribal, and local levels that have a role in regulating ISL facilities are identified and discussed.

- **Waste Management**. Potential impacts from the generation, handling, treatment, and final disposal of chemical, radiological, and municipal wastes are addressed.

- **Accidents**. Potential accident conditions are assessed in the GEIS. These include consideration of a range of possible accidents and estimation of their consequences, including well field leaks and spills, excursions, processing chemical spills, and ion-exchange resin and yellowcake transportation accidents.

- **Environmental Justice**. Although not required for a GEIS, to facilitate subsequent site-specific analyses, this GEIS provides a first order definition of minority and low income populations. Early consultations will be initiated with some of these populations, and the potential for disproportionately high and adverse impacts from future ISL licensing in the uranium milling regions will be evaluated in the event ISL license applications are submitted.

- **Cumulative Impacts**. The GEIS addresses cumulative impacts from proposed ISL facility construction, operation, groundwater restoration, and decommissioning on all aspects of the affected environment, by identifying past, present, and reasonably foreseeable future actions in the uranium milling regions.

- **Monitoring**. The GEIS discusses various monitoring methodologies and techniques used to detect and mitigate the spread of radiological and nonradiological contaminants beyond ISL facility boundaries.

SIGNIFICANCE LEVELS

In the GEIS, NRC has categorized the potential environmental impacts using significance levels. According to the Council on Environmental Quality, the significance of impacts is determined by examining both context and intensity (40 CFR 1508.27). Context is related to the affected region, the affected interests, and the locality, while intensity refers to the severity of the impact, which is based on a number of considerations. In this GEIS, the NRC used the significance levels identified in NUREG–1748:

- SMALL Impact: The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource considered.

- MODERATE Impact: The environmental effects are sufficient to alter noticeably, but not destabilize, important attributes of the resource considered.

- LARGE Impact: The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource considered.

SUMMARY OF IMPACTS

Chapter 4 of the GEIS provides NRC's evaluation of the potential environmental impacts of the construction, operation, aquifer restoration, and decommissioning at an ISL facility in each of the four uranium milling regions. A summary of this evaluation by environmental resource area and phase of the ISL facility lifecycle is provided next.

Land Use Impacts

CONSTRUCTION—Land use impacts could occur from land disturbances (including alterations of ecological cultural or historic resources) and access restrictions (including limitations on other mineral extraction activities, grazing activities, or recreational activities). The potential for land use conflicts could increase in areas with higher percentages of private land ownership and Native American land ownership or in areas with a complex patchwork of land ownership. Land disturbances during construction would be temporary and limited to small areas within permitted boundaries. Well sites, staging areas, and trenches would be reseeded and restored. Unpaved access roads would remain in use until decommissioning. Competing access to mineral rights could be either delayed for the duration of the ISL project or be intermixed with ISL operations (e.g., oil and gas exploration). Changes to land use access including grazing restrictions and impacts on recreational activities would be limited due to the small size of restricted areas, temporary nature of restrictions, and availability of other land for these activities. Ecological, historical, and cultural resources could be affected, but would be protected by careful planning and surveying to help identify resources and avoid or mitigate impacts. For all land use aspects except ecological, historical, and cultural resources, the potential impacts would be SMALL. Due to the potential for unidentified resources to be altered or destroyed during excavation, drilling, and grading, the potential impacts to ecological, historical, or cultural resources would be SMALL to LARGE, depending on local conditions.

OPERATION—The types of land use impacts for operational activities would be similar to construction impacts regarding access restrictions because the infrastructure would be in place. Additional land disturbances would not occur from conducting operational activities. Because access restriction and land disturbance related impacts would be similar to, or less than, those for construction, the overall potential impacts to land use from operational activities would be SMALL.

AQUIFER RESTORATION—Due to the use of the same infrastructure, land use impacts would be similar to operations during aquifer restoration, although some operational activities would diminish—SMALL.

DECOMMISSIONING—Land use impacts would be similar to those described for construction with a temporary increase in land-disturbing activities for dismantling, removing, and disposing of facilities, equipment, and excavated contaminated soils. Reclamation of land to preexisting conditions and uses would help mitigate potential impacts—SMALL to MODERATE during decommissioning, and SMALL once decommissioning is completed.

Transportation Impacts

CONSTRUCTION—Low magnitude traffic generated by ISL construction relative to local traffic counts would not significantly increase traffic or accidents on many of the roads in the region. Existing low traffic roads could be moderately impacted by the additional worker commuting traffic during periods of peak employment. This impact would be expected to be more pronounced in areas with relatively lower traffic counts. Moderate dust, noise, and incidental

wildlife or livestock kill impacts would be possible on, or near, site access roads (dust in particular for unpaved access roads)—SMALL to MODERATE.

OPERATION—Low magnitude traffic relative to local traffic counts on most roads would not significantly increase traffic or accidents. Existing low traffic roads could be moderately impacted by commuting traffic during periods of peak employment including dust, noise, and possible incidental wildlife or livestock kill impacts on or near site access roads. High consequences would be possible for a severe accident involving transportation of hazardous chemicals in a populated area. However, the probability of such accidents occurring would be low owing to the small number of shipments, comprehensive regulatory controls, and use of best management practices. For radioactive material shipments (yellowcake product, ion-exchange resins, waste materials), compliance with transportation regulations would limit radiological risk for normal operations. Low radiological risk is estimated for accident conditions. Emergency response protocols would help mitigate long-term consequences of severe accidents involving release of uranium—SMALL to MODERATE.

AQUIFER RESTORATION—The magnitude of transportation activities would be lower than for construction and operations, with the exception of workforce commuting, which could have moderate impacts on, or in the vicinity of, existing low traffic roads—SMALL to MODERATE.

DECOMMISSIONING—The types of transportation activities, and therefore the types of impacts, would be similar to those discussed for construction and operations, except the magnitude of transportation activities (e.g., number and types of waste and supply shipments, no yellowcake shipments) from decommissioning could be lower than for operations. Accident risks would be bounded by the operations yellowcake transportation risk estimates—SMALL.

Geology and Soils Impacts

CONSTRUCTION—Disturbance to soil would occur from construction (clearing, excavation, drilling, trenching, road construction); however, such disturbances would be expected to be temporary, disturbed areas would be small (approximately 15 percent of the total site area), and potential impacts would be mitigated by using best management practices. A large portion of the well fields, trenches, and access roads would be restored and reseeded after construction. Excavated soils would be stockpiled, seeded, and stored onsite until needed for reclamation fill. No impacts to subsurface geological strata would be likely—SMALL.

OPERATION—Temporary contamination or alteration of soils would be likely from operational leaks and spills and possible from transportation, use of evaporation ponds, or land application of treated waste water. However, detection and response to leaks and spills (e.g., soil cleanup), monitoring of treated waste water, and eventual survey and decommissioning of all potentially impacted soils would limit the magnitude of overall impacts to soils—SMALL.

AQUIFER RESTORATION—Impacts to geology and soils from aquifer restoration activities would be similar to impacts from operations due to use of the same infrastructure and similar activities conducted (e.g., well field operation, transfer activities, liquid effluent treatment and disposal)—SMALL.

DECOMMISSIONING—Impacts to geology and soils from decommissioning would be similar to impacts from construction. Activities to clean up, recontour, and reclaim disturbed lands during decommissioning would mitigate long-term impacts to soils—SMALL.

Surface Water Impacts

CONSTRUCTION—Impacts to surface waters and related habitats from construction (road crossings, filling, erosion, runoff, spills or leaks of fuels and lubricants for construction equipment) would be mitigated through proper planning, design, construction methods, and best management practices. Some impacts directly related to the construction activities would be temporary and limited to the duration of the construction period. U.S. Army Corps of Engineers permits may be required when filling and crossing of wetlands. Temporary changes to spring and stream flow from grading and changes in topography and natural drainage patterns could be mitigated or restored after the construction phase. Impacts from incidental spills of drilling fluids into local streams could occur, but would be temporary due to the use of mitigation measures. Impacts from roads, parking areas, and buildings on recharge to shallow aquifers would be SMALL, owing to the limited area of impervious surfaces proposed. Impacts from infiltration of drilling fluids into the local aquifer would be localized, small, and temporary—SMALL to MODERATE depending on site-specific characteristics.

OPERATION—Through permitting processes, federal and state agencies regulate the discharge of storm water runoff and the discharge of process water. Impacts from these discharges would be mitigated as licensees would operate within the conditions of their permits. Expansion of facilities or pipelines during operations would generate impacts similar to construction—SMALL to MODERATE depending on site-specific characteristics.

AQUIFER RESTORATION—Impacts from aquifer restoration would be similar to impacts from operations due to use of the same (in-place) infrastructure and similar activities conducted (e.g., well field operation, transfer of fluids, water treatment, storm water runoff)—SMALL to MODERATE depending on site-specific characteristics.

DECOMMISSIONING—Impacts from decommissioning would be similar to impacts from construction. Activities to clean up, recontour, and reclaim disturbed lands during decommissioning would mitigate long-term impacts to surface waters—SMALL to MODERATE depending on site-specific characteristics.

Groundwater Impacts

CONSTRUCTION—Water use impacts would be limited by the small volumes of groundwater used for routine activities such as dust suppression, mixing cements, and drilling support over short and intermittent periods. Contamination of groundwater from construction activities would be mitigated by best management practices—SMALL.

OPERATION—Potential impacts to shallow aquifers can occur from leaks or spills from surface facilities and equipment. Shallow aquifers are important sources of drinking water in some areas of the four uranium milling regions. Potential impacts to the ore-bearing and surrounding aquifers include consumptive water use and degradation of water quality (from normal production activities, off-normal excursion events, and deep well injection disposal practices). Consumptive use impacts from withdrawal of groundwater would occur because approximately 1 to 3 percent of pumped groundwater is not returned to the aquifer (e.g., process bleed). That amount of water lost could be reduced substantially by available treatment methods (e.g., reverse osmosis, brine concentration). Effects of water withdrawal on groundwater would be expected to be SMALL as the ore zone normally occurs in a confined aquifer. Estimated drawdown effects vary depending on site conditions and water treatment technology applied. Excursions of lixiviant and mobilized chemical constituents could occur from failure of well seals or other operational conditions that result in incomplete recovery of lixiviant. Well-seal-related

excursions would be detected by the groundwater monitoring system, and periodic well mechanical integrity testing, and impacts would be expected to be mitigated during operation or aquifer restoration. Other excursions could result in plumes of mobilized uranium and heavy metals extending beyond the mineralization zone. The magnitude of potential impacts from vertical excursions would vary depending on site-specific conditions. To reduce the likelihood and consequences of potential excursions at ISL facilities, NRC requires licensees to take preventative measures prior to starting operations, including well tests, monitoring, and development of procedures that include excursion response measures and reporting requirements. Impacts from the alterations of ore body aquifer chemistry would be SMALL, because the aquifer would (1) be confined, (2) not be a potential drinking water source, and (3) be expected to be restored during the restoration period. Potential environmental impacts to confined deep aquifers below the production aquifers from deep well injection of processing wastes would be addressed by the underground injection permitting process regulated by the states and NRC's approval process—SMALL to LARGE, depending on site-specific conditions.

AQUIFER RESTORATION—Potential impacts would be from consumptive use and potential deep disposal of brine slurries after reverse osmosis, if applicable. The volume of water removed from the aquifer and related impacts would be dependent on site-specific conditions and the type of water treatment technology the facility uses. In some cases, groundwater consumptive use for the aquifer restoration has been reported to be less than groundwater use during the ISL operation, and drawdowns due to aquifer restorations have been smaller than drawdown caused by ISL operations. Potential environmental impacts associated with water consumption during aquifer restorations are determined by (1) the restoration techniques chosen, (2) the volume of water to be used, (3) the severity and extent of the contamination, and (4) the current and future use of the production and surrounding aquifers near the ISL facility or at the regional scale—SMALL to MODERATE, depending on site-specific conditions.

DECOMMISSIONING—Potential impacts from decommissioning would be similar to construction (water use, spills) with an additional potential to mobilize contaminants during demolition and cleanup activities. Contamination of groundwater from decommissioning activities would be mitigated by implementation of an NRC-approved decommissioning plan and use of best management practices—SMALL.

Terrestrial Ecology Impacts

CONSTRUCTION—Potential terrestrial ecology impacts would include the removal of vegetation from the well fields and the milling site, the modification of existing vegetative communities, the loss of sensitive plants and habitats from clearing and grading, and the potential spread of invasive species and noxious weed populations. These impacts would be expected to be temporary because restoration and reseeding occur rapidly after the end of construction. Introduction of invasive species and noxious weeds would be mitigated by restoration and reseeding after construction. Shrub and tree removal and loss would take longer to restore. Construction noise could affect reproductive success of sage-grouse leks by interfering with mating calls. Temporary displacement of some animal species would also occur. Critical wintering and year-long ranges are important to survival of both big game and sage-grouse. Raptors breeding onsite may be impacted by construction activities or milling operations, depending on the time of year construction occurs. Wildlife habitat fragmentation, temporary displacement of animal species, and direct or indirect mortalities would be possible. Implementation of wildlife surveys and mitigation measures following established guidelines would limit impacts. The magnitude of impacts depends on whether a new facility is being licensed or an existing facility is being extended—SMALL to MODERATE, depending on site-specific habitat conditions.

OPERATION—Habitats could be altered by operations (fencing, traffic, noise), and individual takes could occur due to conflicts between species habitat and operations. Access to crucial wintering habitat and water could be limited by fencing. However, the State of Wyoming Game and Fish Department specifies fencing construction techniques to minimize impediments to big game movement. Migratory birds could be affected by exposure to constituents in evaporation ponds, but perimeter fencing and netting would limit impacts. Temporary contamination or alteration of soils would be likely from operational leaks and spills and possible from transportation or land application of treated waste water. However, detection and response to leaks and spills (e.g., soil cleanup) and eventual survey and decommissioning of all potentially impacted soil limit the magnitude of overall impacts to terrestrial ecology. Mitigation measures such as perimeter fencing, netting, alternative sites, and periodic wildlife surveys would reduce overall impacts—SMALL.

AQUIFER RESTORATION—Impacts include habitat disruption, but existing (in-place) infrastructure would be used during aquifer restoration, with little additional ground disturbance. Migratory birds could be affected by exposure to constituents in evaporation ponds, but perimeter fencing and netting would limit impacts. Contamination of soils could result from leaks and spills and land application of treated waste water. However, detection and response techniques, and eventual survey and decommissioning of all potentially impacted soils, would limit the magnitude of overall impacts to terrestrial ecology. Mitigation measures such as perimeter fencing, netting, and alternative sites would reduce overall impacts—SMALL.

DECOMMISSIONING—During decommissioning and reclamation, there would be a temporary disturbance to land (e.g., excavated soils, buried piping, removal of structures). However, revegetation and recontouring would restore habitat altered during construction and operations. Wildlife would be temporarily displaced, but are expected to return after decommissioning and reclamation are completed and vegetation and habitat are reestablished—SMALL to MODERATE, depending on site-specific conditions.

Aquatic Ecology Impacts

CONSTRUCTION—Clearing and grading activities associated with construction could result in a temporary increase in sediment load in local streams, but aquatic species would recover quickly as sediment load decreases. Clearing of riparian vegetation could affect light and thus the temperature of water. Construction impacts to wetlands would be identified and managed through U.S. Army Corps of Engineers permits, as appropriate. Construction impacts to surface waters and aquatic species would be temporary and mitigated by best management practices—SMALL.

OPERATION—Impacts could result from spills or releases into surface water. Impacts would be minimized by spill prevention, identification, and response programs, and National Pollutant Discharge Elimination System (NPDES) permit requirements—SMALL.

AQUIFER RESTORATION—Activities would use existing (in-place) infrastructure, and impacts could result from spills or releases of untreated groundwater. Impacts would be minimized by spill prevention, identification, and response programs, and NPDES permit requirements—SMALL.

DECOMMISSIONING—Decommissioning and reclamation activities could result in temporary increases in sediment load in local streams, but aquatic species would recover quickly as

sediment load decreases. With completion of decommissioning, revegetation, and recontouring, habitat would be reestablished and impacts would, therefore, be limited—SMALL.

Threatened and Endangered Species Impacts

CONSTRUCTION—Numerous threatened and endangered species and state species of concern are located in the four uranium milling regions. Small fragmentation of habitats would occur, but most species readapt quickly. The magnitude of impact would depend on the size of a new facility or extension to an existing facility and the amount of land disturbance. Inventory of threatened or endangered species would be developed during site-specific reviews to identify unique or special habitats, and Endangered Species Act consultations conducted with the U.S. Fish and Wildlife Service would assist in reducing impacts—SMALL to LARGE—depending on site-specific habitat and presence of threatened or endangered species.

OPERATION—Impacts could result from individual takes due to conflicts with operations. Small fragmentation of habitats would occur, but most species readapt quickly. The magnitude of impact would depend on the size of a new facility or extension to an existing facility and the amount of land disturbance. Impacts could potentially result from spills or permitted effluents, but would be minimized through the use of spill prevention measures, identification and response programs, and NPDES permit requirements. Inventory of threatened or endangered species developed during site-specific reviews would identify unique or special habitats, and Endangered Species Act consultations conducted with the U.S. Fish and Wildlife Service would assist in reducing impacts—SMALL to LARGE—depending on site-specific habitat and presence of threatened or endangered species.

AQUIFER RESTORATION—Impacts could result from individual takes due to conflicts with aquifer restoration activities (equipment, traffic). Existing (in-place) infrastructure would be used during aquifer restoration, so additional land-disturbing activities and habitat fragmentation would not be anticipated. Impacts may result from spills or releases of treated or untreated groundwater, but impacts would be minimized through the use of spill prevention measures, identification and response programs, and NPDES permit requirements. Inventory of threatened or endangered species would be developed during site-specific reviews to identify unique or special habitats, and Endangered Species Act consultations with the U.S. Fish and Wildlife Service would assist in reducing impacts—SMALL.

DECOMMISSIONING—Impacts resulting from individual takes would occur due to conflicts with decommissioning activities (equipment, traffic). Temporary land disturbance would occur as structures are demolished and removed and the ground surface is recontoured. Inventory of threatened or endangered species developed during site-specific environmental review of the decommissioning plan would identify unique or special habitats, and Endangered Species Act consultations with the U.S. Fish and Wildlife Service would assist in reducing impacts. With completion of decommissioning, re-vegetation, and re-contouring, habitat would be reestablished and impacts would, therefore, be limited—SMALL to LARGE.

Air Quality Impacts

CONSTRUCTION—Fugitive dust and combustion (vehicle and diesel equipment) emissions during land-disturbing activities associated with construction would be small, short-term, and reduced through best management practices (e.g., dust suppression). For example, estimated fugitive dust emissions during ISL construction are less than 2 percent of the National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ and less than 1 percent for PM_{10}. For NAAQS attainment areas, nonradiological air quality impacts would be SMALL. A Prevention of

Significant Deterioration Class I area exists in only one of the four regions (Wind Cave National Park in the Nebraska-South Dakota-Wyoming Region). More stringent air quality standards would apply to a facility that impacts the air quality of that area. If impacts were initially assessed at a higher significance level, permit requirements would impose conditions or mitigation measures to reduce impacts—SMALL.

OPERATION—Radiological impacts can result from dust releases from drying of lixiviant pipeline spills, radon releases from well system relief valves, resin transfer or elution, and gaseous/particulate emissions from yellowcake dryers. Only small amounts of low dose materials would be expected to be released based on operational controls and rapid response to spills. Required spill prevention, control, and response procedures would be used to minimize impacts from spills. HEPA filters and vacuum dryer designs reduce particulate emissions from operations, and ventilation reduces radon buildup during operations. Compliance with the NRC-required radiation monitoring program would ensure releases are within regulatory limits. Other potential nonradiological emissions during operations include fugitive dust and fuel from equipment, maintenance, transport trucks, and other vehicles. For NAAQS attainment areas, nonradiological air quality impacts would be SMALL. A Prevention of Significant Deterioration Class I area is located in the Nebraska-South Dakota-Wyoming Region (Wind Cave National Park). More stringent air quality standards would apply to a facility that impacts the air quality of that area. If impacts were initially assessed at a higher significance level, permit requirements would impose conditions or mitigation measures to reduce impacts—SMALL.

AQUIFER RESTORATION—Because the same infrastructure is used, air quality impacts are expected to be similar to, or less than, those during operations. For NAAQS attainment areas, nonradiological air quality impacts would be SMALL. Where a Prevention of Significant Deterioration Class I area exists, such as the Wind Cave National Park in the Nebraska-South Dakota-Wyoming Region, more stringent air quality standards would apply to a facility that impacts the air quality. If impacts were initially assessed at a higher significance level, permit requirements would impose conditions or mitigation measures to reduce impacts—SMALL.

DECOMMISSIONING—Fugitive dust, vehicle, and diesel emissions during land-disturbing activities associated with decommissioning would be similar to, or less than, those associated with construction, would be short-term, and would be reduced through best management practices (e.g., dust suppression). Potential impacts would decrease as decommissioning and reclamation of disturbed areas are completed. For NAAQS attainment areas, nonradiological air quality impacts would be SMALL. However, where a Prevention of Significant Deterioration Class I area exists (Wind Cave National Park in the Nebraska-South Dakota-Wyoming Region), more stringent air quality standards would apply to a facility that impacts the air quality of that area. If impacts were initially assessed at a higher significance level, permit requirements would impose conditions or mitigation measures to reduce impacts—SMALL.

Noise Impacts

CONSTRUCTION—Noise generated during construction would be noticeable in proximity to operating equipment, but would be temporary (typically daytime only). Administrative and engineering controls would be used to maintain noise levels in work areas below Occupational Health and Safety Administration (OSHA) regulatory limits and mitigated by use of personal hearing protection. Traffic noise during construction (commuting workers, truck shipments to and from the facility, and construction equipment such as trucks, bulldozers, and compressors) would be localized, and limited to highways in the vicinity of the site, access roads within the site, and roads in the well fields. Relative increases in traffic levels would be SMALL for the

larger roads, but may be MODERATE for lightly traveled rural roads through smaller communities. Noise may also adversely affect wildlife habitat and reproductive success in the immediate vicinity of construction activities. Noise levels decrease with distance, and at distances more than about 300 m [1,000 ft], ambient noise levels would return to background. Wildlife avoid construction areas because of noise and human activity. Generally, the uranium districts are located more than 300 m [1,000 ft] from the closest community. As a result, noise impacts would be SMALL to MODERATE.

OPERATION—Noise-generating activities in the central uranium processing facility would be indoors, reducing offsite sound levels. Well field equipment (e.g., pumps, compressors) would be contained within structures (e.g., header houses, satellite facilities), also reducing sound levels to offsite receptors. Administrative and engineering controls would be used to maintain noise levels in work areas below OSHA regulatory limits and mitigated by use of personal hearing protection. Traffic noise from commuting workers, truck shipments to and from the facility, and facility equipment would be expected to be localized, limited to highways in the vicinity of the site, access roads within the site, and roads in well fields. Relative increases in traffic levels would be SMALL for the larger roads, but may be MODERATE for lightly traveled rural roads through smaller communities. Most noise would be generated indoors and mitigated by regulatory compliance and best management practices. Noise from trucks and other vehicles is typically of short duration. Also, noise usually is not discernable to offsite receptors at distances of more than 300 m [1,000 ft.] Generally, the uranium districts are located more than 300 m [1,000 ft] from the closest community—SMALL to MODERATE.

AQUIFER RESTORATION—Noise generation is expected to be less than during construction and operations. Pumps and other well field equipment contained in buildings reduce sound levels to offsite receptors. Existing operational infrastructure would be used, and traffic levels would be expected to be less than those during construction and operations. There are additional sensitive areas that should be considered within some of the regions, but because of decreasing noise levels with distance, aquifer restoration activities would have only SMALL and temporary noise impacts for residences, communities, or sensitive areas, especially those located more than about 300 m [1,000 ft] from specific noise-generating activities. Noise usually is not discernable to offsite receptors at distances more than 300 m [1,000 ft]. Generally, the uranium districts are located more than 300 m [1,000 ft] from the closest community—SMALL to MODERATE.

DECOMMISSIONING—Noise generated during decommissioning would be noticeable only in proximity to equipment and temporary (typically daytime only). Administrative and engineering controls would be used to maintain noise levels in work areas below OSHA regulatory limits and mitigated by use of personal hearing protection. Noise levels during decommissioning would be less than during construction and would diminish as less and less equipment is used and truck traffic is reduced. Noise usually is not discernable to offsite receptors at distances more than 300 m [1,000 ft]. Generally, the uranium districts are located more than 300 m [1,000 ft] from the closest community—SMALL to MODERATE.

Historical and Cultural Resources Impacts

CONSTRUCTION—Potential impacts during ISL facility construction could include loss of, or damage and temporary restrictions on access to, historical, cultural, and archaeological resources. The eligibility evaluation of cultural resources for listing in the National Register of Historic Places (NRHP) under criteria in 36 CFR 60.4(a)–(d) and/or as Traditional Cultural Properties (TCP) would be conducted as part of the site-specific review and NRC licensing procedures undertaken during the NEPA review process. The evaluation of impacts to any

historic properties designated as TCPs and tribal consultations regarding cultural resources and TCPs also occurs during the site-specific licensing application and review process. To determine whether significant cultural resources would be avoided or mitigated, consultations with State Historic Preservation Offices (SHPO), other government agencies (e.g., U.S. Fish and Wildlife Service and State Environmental Departments), and Native American Tribes (the THPO) occur as part of the site-specific review. Additionally, as needed, the NRC license applicant would be required, under conditions in its NRC license, to adhere to procedures regarding the discovery of previously undocumented cultural resources during initial construction. These procedures typically require the licensee to stop work and to notify the appropriate federal, tribal, and state agencies with regard to mitigation measures—SMALL or MODERATE to LARGE depending on site-specific conditions.

OPERATION—Because less land disturbance occurs during the operations phase, potential impacts to historical, cultural, and archaeological resources would be less than during construction. Conditions in the NRC license requiring adherence to procedures regarding the discovery of previously undocumented cultural resources would apply during operation. These procedures typically require the licensee to stop work and to notify the appropriate federal, tribal, and state agencies with regard to mitigation measures—SMALL, depending on site-specific conditions.

AQUIFER RESTORATION—Because less land disturbance occurs during the aquifer restoration phase, potential impacts to historical, cultural, and archaeological resources would be less than those during construction. Conditions in the NRC license requiring adherence to procedures regarding the discovery of previously undocumented cultural resources would apply during aquifer restoration. These procedures typically require the licensee to stop work and to notify the appropriate federal, tribal, and state agencies with regard to mitigation measures—SMALL, depending on site-specific conditions.

DECOMMISSIONING—Because less land disturbance occurs during the decommissioning phase and because decommissioning and reclamation activities would be focused on previously disturbed areas, potential impacts to historical, cultural, and archaeological resources would be less than during construction. Conditions in the NRC license requiring adherence to procedures regarding the discovery of previously undocumented cultural resources would apply during decommissioning and reclamation. These procedures typically require the licensee to stop work and to notify the appropriate federal, tribal, and state agencies with regard to mitigation measures—SMALL, depending on site-specific conditions.

Visual and Scenic Impacts

CONSTRUCTION—Visual impacts result from equipment (drill rig masts, cranes), dust/diesel emissions from construction equipment, and hillside and roadside cuts. Most of the four uranium milling regions are classified as Visual Resource Management (VRM) Class II through IV by the U.S. Bureau of Land Management. A number of VRM Class II areas surround national monuments (El Morro and El Malpais), the Chaco Culture National Historic Park, and sensitive areas managed within the Mount Taylor district in the Northwestern New Mexico Uranium Milling District and would have the greatest potential for impacts to visual resources. Most of these areas, however, are located away from potential ISL facilities at distances greater than 16 km [10 mi]. Most potential facilities are located in VRM Class III and IV areas. The general visual and scenic impacts associated with ISL facility construction would be temporary and SMALL, but from a Native American perspective, any construction activities would likely result in adverse impacts to the landscape, particularly for facilities located in areas within view of tribal lands and areas of special significance such as Mount Taylor. As previously discussed,

a Prevention of Significant Deterioration Class I area (Wind Cave National Park) is located in the Nebraska-South Dakota-Wyoming Uranium Milling Region. Prevention of Significant Deterioration Class I areas require more stringent air quality standards that can affect visual impacts. Nevertheless, most potential visual impacts during construction would be temporary as equipment is moved and would be mitigated by best management practices (e.g., dust suppression). Because these sites are in sparsely populated areas and there is generally rolling topography of the region, most visual impacts during construction would not be visible from more than about 1 km [0.6 mi]. The visual impacts associated with ISL construction would be consistent with the predominant VRM Class III and IV—SMALL.

OPERATION—Visual impacts during operations would be less than those associated with construction. Most of the well field surface infrastructure has a low profile, and most piping and cables would be buried. The tallest structures include the central uranium processing facility {10 m [30 ft]} and power lines {6 m [20 ft]}. Because these sites are in sparsely populated areas and there is generally rolling topography of the regions, most visual impacts during operations would not be visible from more than about 1 km [0.6 mi]. Irregular layout of well field surface structures such as wellhead protection and header houses would further reduce visual contrast. Best management practices, and design (e.g., painting buildings) and landscaping techniques would be used to mitigate potential visual impact. The uranium districts in the four regions are all located more than 16 km [10 mi] from the closest VRM Class II region, and the visual impacts associated with ISL construction would be consistent with the predominant VRM Class III and IV—SMALL.

AQUIFER RESTORATION—Aquifer restoration activities would use in-place infrastructure. As a result, potential visual impacts would be the same as, or less than, those during operations—SMALL.

DECOMMISSIONING—Because similar equipment would be used and activities conducted, potential visual impacts during decommissioning would be the same as, or less than, those during construction. Most potential visual impacts during decommissioning would be temporary as equipment is moved and would be mitigated by best management practices (e.g., dust suppression). Visual impacts would be low, because these sites are in sparsely populated areas, and impacts would diminish as decommissioning activities decrease. An approved site reclamation plan is required prior to license termination, with the goal of returning the landscape to preconstruction conditions (predominantly VRM Class III and IV). Some roadside cuts and hill slope modifications, however, may persist beyond decommissioning and reclamation—SMALL.

Socioeconomic Impacts

CONSTRUCTION—Potential impacts to socioeconomics would result predominantly from employment at an ISL facility and demands on the existing public and social services, tourism/recreation, housing, infrastructure (schools, utilities), and the local work force. Total peak employment would be about 200 people, including company employees and local contractors, depending on timing of construction with other stages of the ISL lifecycle. During construction of surface facilities and well fields, the general practice would be to use local contractors (drillers, construction), as available. A local multiplier of 0.7 (U.S. Bureau of the Census) is used to indicate how many ancillary jobs could be created (in this case about 140). For example, local building materials and building supplies would be used to the extent practical. Most employees would live in larger communities with access to more services. Some construction employees, however, would commute from outside the county to the ISL facility, and skilled employees (e.g., engineers, accountants, managers) would come from outside the

local work force. Some of these employees would temporarily relocate to the project area and contribute to the local economy through purchasing goods and services and taxes. Because of the small relative size of the ISL workforce, net impacts would be SMALL to MODERATE.

OPERATION—Employment levels for ISL facility operations would be less than those for construction, with total peak employment depending on timing and overlap with other stages of the ISL lifecycle. Use of local contract workers and local building materials would diminish, because drilling and facility construction would diminish. Revenues would be generated from federal, state, and local taxes on the facility and the uranium produced. Employment types would be similar to construction, but the socioeconomic impacts would be less due to fewer employees—SMALL to MODERATE.

AQUIFER RESTORATION—In-place infrastructure would be used for aquifer restoration, and employment levels would be similar to those for operations—SMALL to MODERATE.

DECOMMISSIONING—A skill set similar to the construction workforce would be involved in dismantling surface structures, removing pumps, plugging and abandoning wells, and reclaiming/recontouring the ground surface. Employment levels and use of local contractor support during decommissioning would be similar to those required for construction. Employment would be temporary, however, as decommissioning activities are short in duration. Because of similar employment levels, other socioeconomic impacts would be similar to construction—SMALL to MODERATE.

Public and Occupational Health and Safety Impacts

CONSTRUCTION—Worker safety would be addressed by standard construction safety practices. Fugitive dust would result from construction activities and vehicle traffic, but would likely be of short duration and would not result in a radiological dose. Diesel emissions would also be of short duration and readily dispersed into the atmosphere—SMALL to MODERATE.

OPERATION—Potential occupational radiological impacts from normal operations would result from (1) exposure to radon gas from the well field, (2) ion-exchange resin transfer operations, and (3) venting during processing activities. Workers would also be exposed to airborne uranium particulates from dryer operations and maintenance activities. Potential public exposures to radiation could occur from the same radon releases and uranium particulate releases (i.e., from facilities without vacuum dryer technology). Both worker and public radiological exposures are addressed in NRC regulations at 10 CFR Part 20, which require licensees to implement an NRC-approved radiation protection program. (Measured and calculated doses for workers and the public are commonly only a fraction of regulated limits.) Nonradiological worker safety matters are addressed through commonly applied occupational health and safety regulations and practices. Radiological accident risks could involve processing equipment failures leading to yellowcake slurry spills, or radon gas or uranium particulate releases. Consequences of accidents to workers and the public are generally low, with the exception of a dryer explosion which could result in worker dose above NRC limits. The likelihood of such an accident would be low, and therefore the risk would also be low. Potential nonradiological accidents impacts include high consequence chemical release events (e.g., ammonia) for both workers and nearby populations. The likelihood, however, of such release events would be low based on historical operating experience at NRC-licensed facilities, primarily due to operators following commonly applied chemical safety and handling protocols—SMALL to MODERATE.

AQUIFER RESTORATION—Activities during aquifer restoration overlap with similar activities during operations (e.g., operation of well fields, waste water treatment and disposal). The resultant impacts on public and occupational health and safety would be bound by operational impacts. The reduction of some operational activities (e.g., yellowcake production and drying, remote ion exchange) will limit the relative magnitude of potential worker and public health and safety hazards—SMALL.

DECOMMISSIONING—Worker and public health and safety would be addressed in a NRC-required decommissioning plan. This plan details how a 10 CFR Part 20 compliant radiation safety program would be implemented during decommissioning, how ensuring the safety of workers and the public would be maintained, and how applicable safety regulations would be complied with—SMALL.

Waste Management Impacts

CONSTRUCTION—Relatively small-scale construction activities (Section 2.3) and incremental well field development at ISL facilities would generate low volumes of construction waste—SMALL.

OPERATION—Operational wastes primarily result from liquid waste streams including process bleed, flushing of depleted eluant to limit impurities, resin transfer wash, filter washing, uranium precipitation process wastes (brine), and plant wash down water. State permit actions, NRC license conditions, and NRC inspections ensure the proper practices would be used to comply with safety requirements to protect workers and the public. Waste treatments such as reverse osmosis and radium settling would be used to segregate wastes and minimize disposal volumes. Potential impacts from surface discharge and deep well injection would be limited by the conditions specified in the applicable state permit. NRC regulations address constructing, operating, and monitoring for leakage of evaporation ponds used to store and reduce volumes of liquid wastes. Potential impacts from land application of treated wastewater would be addressed by NRC review of site-specific conditions prior to approval and routine monitoring in decommissioning surveys. Offsite waste disposal impacts would be SMALL for radioactive wastes as a result of required preoperational disposal agreements. Impacts for hazardous and municipal waste would also be SMALL due to the volume of wastes generated. For remote areas with limited available disposal capacity, such wastes may need to be shipped greater distances to facilities that have capacity; however, the volume of wastes generated and magnitude of such shipments are estimated to be low—SMALL.

AQUIFER RESTORATION—Waste management activities during aquifer restoration would use the same treatment and disposal options implemented for operations. Therefore, impacts associated with aquifer restoration would be similar to operational impacts. While the amount of wastewater generated during aquifer restoration would be dependent on site-specific conditions, the potential exists for additional wastewater volume and associated treatment wastes during the restoration period. However, this would be offset to some degree by the reduction in production capacity from the removal of a well field. NRC review of future ISL facility applications would verify that sufficient water treatment and disposal capacity (and the associated agreement for disposal of byproduct material) are addressed. As a result, waste management impacts from aquifer restoration would be SMALL.

DECOMMISSIONING—Radioactive wastes from decommissioning ISL facilities (including contaminated excavated soil, evaporation pond bottoms, process equipment) would be disposed of as byproduct material at an NRC-licensed facility. A preoperational agreement with a licensed disposal facility to accept radioactive wastes ensures sufficient disposal capacity

would be available for byproduct wastes generated by decommissioning activities. Safe handling, storage, and disposal of decommissioning wastes would be addressed in a required decommissioning plan for NRC review prior to starting decommissioning activities. Such a plan would detail how a 10 CFR Part 20 compliant radiation safety program would be implemented during decommissioning to ensure the safety of workers and the public and compliance with applicable safety regulations. Overall, volumes of decommissioning radioactive, chemical, and solid wastes would be SMALL.

ABBREVIATIONS/ACRONYMS

BLM	U.S. Bureau of Land Management
CBSA	Core-Based Statistical Area
CEA	Cumulative Effects Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CEQ	Council on Environmental Quality
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FONSI	Finding of No Significant Impact
GEIS	Generic Environmental Impact Statement
ISL	*In-situ* Leach
MIT	Mechanical Integrity Testing
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NDEQ	Nebraska Department of Environmental Quality
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
PVC	Polyvinyl Chloride
RFFA	Reasonably Foreseeable Future Action
SHPO	State Historic Preservation Officer
TDS	Total Dissolved Solids
THPO	Tribal Historic Preservation Officer
UCL	Upper Control Limit
UIC	Underground Injection Control
UMTRCA	Uranium Mill Tailings Radiation Control Act
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
VRM	Visual Resource Management
WDEQ	Wyoming Department of Environmental Quality

SI* (MODERN METRIC) CONVERSION FACTORS

Approximate Conversions From SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
Length				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
Area				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
Volume				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
m^3	cubic meters	0.0008107	acre-feet	acre-feet
Mass				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
Temperature (Exact Degrees)				
°C	Celsius	1.8 °C + 32	Fahrenheit	°F

*SI is the symbol for the International System of Units. Appropriate rounding should be performed to comply with Section 4 of ASTM E380 (ASTM International. "Standard for Metric Practice Guide." West Conshohocken, Pennsylvania: ASTM International. Revised 2003.).

1 INTRODUCTION

The Atomic Energy Act and the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) authorize the U.S. Nuclear Regulatory Commission (NRC) to issue licenses for the possession and use of source material and byproduct material. The statutes require NRC to license facilities that meet NRC regulatory requirements that were developed to protect public health and safety from radiological hazards. *In-situ* leach (ISL) uranium milling facilities must meet NRC regulatory requirements in order to obtain this license to operate.

NRC licensing process is designed to assure the safe operation of ISL facilities. In addition to information for a safety evaluation review, license applicants must submit an environmental report as part of their license application. Under the NRC's environmental protection regulations in Title 10, Part 51 of the Code of Federal Regulations (10 CFR Part 51), which implement the National Environmental Policy Act (NEPA), issuance of a new license to possess and use source material for uranium milling requires an environmental impact statement (EIS) or a supplement to an EIS (SEIS). NRC will prepare an EA, SEIS or EIS for applications to amend or renew an existing ISL facility license in accordance to regulatory requirements in 10 CFR Part 51.

> **Generic Environmental Impact Statement (GEIS)**
>
> A GEIS is an environmental impact statement that assesses the scope of the environmental effects that would be associated with an action (such as issuing a license for an ISL facility) at numerous sites. The Commission directed the NRC staff to prepare the GEIS to cover as many of the potential uranium recovery sites as possible.
>
> **Supplemental EIS (SEIS)**
>
> A supplemental EIS updates or supplements an existing EIS (such as the GEIS). The Commission directed the NRC staff to issue site-specific supplements to the GEIS for each new license application.

NRC prepared this Generic Environmental Impact Statement for *In-Situ* Leach Uranium Milling Facilities to help fulfill this requirement. The GEIS was prepared to assess the potential environmental impacts associated with the construction, operation, aquifer restoration, and decommissioning of an ISL facility in four specified geographic areas. The intent of the GEIS is to determine which impacts would be essentially the same for all ISL facilities and which ones would result in varying levels of impacts for different facilities, thus requiring further site-specific information to determine the potential impacts. As such, the GEIS provides a starting point for NRC's NEPA analyses for site-specific license applications for new ISL facilities, as well as for applications to amend or renew existing ISL licenses.

1.1 Rationale of the GEIS

In the GEIS, NRC assesses the environmental impacts that could be associated with an ISL facility in four geographic areas of the western United States. The rationale for developing the GEIS is that ISL facilities use the same or very similar technology such that the potential environmental impacts associated with technology could be assessed on a generic (programmatic) basis. In this way, repetitive reviews of certain of these impacts could be avoided, thus focusing NRC's evaluation on unique issues of concern for each site.

NRC developed this GEIS using (1) knowledge gained during the past 30 years of licensing and regulating these facilities, (2) the active participation of the State of Wyoming as a cooperating agency, and (3) public comments received during the preparation of the GEIS.

NRC structured the GEIS by identifying four geographic regions (Figure 1.1-1) to use for the environmental impact analysis. These regions were identified based on several considerations, including

- Past and existing uranium milling sites are located within states where NRC has regulatory authority over uranium milling.
- Potential new sites are identified based on NRC understanding of where the uranium recovery industry has plans to develop uranium deposits using ISL technology (NRC, 2009).
- Locations of previously identified uranium deposits within portions of Wyoming, Nebraska, South Dakota, and New Mexico (EPA, 2006, 2007) (Figure 1.1-2).

In this GEIS, NRC documents the potential environmental impacts that would be associated with the construction, operation, aquifer restoration, and decommissioning of an ISL facility in

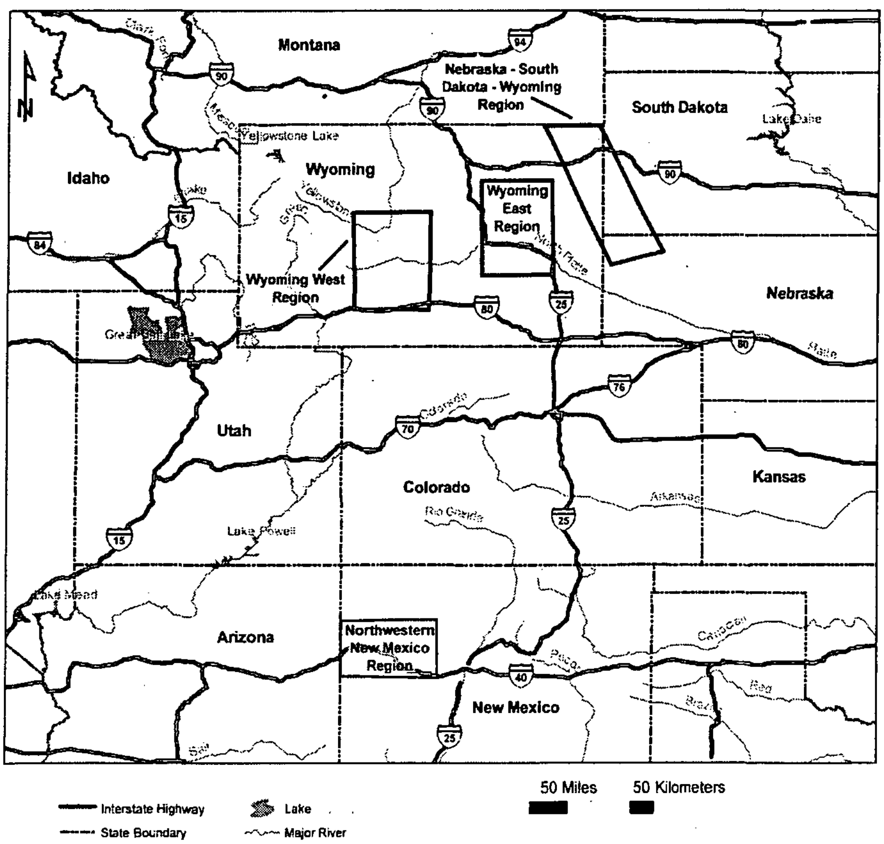

Figure 1.1-1. Four Geographic Regions Used as a Framework for the Analyses Presented in This GEIS

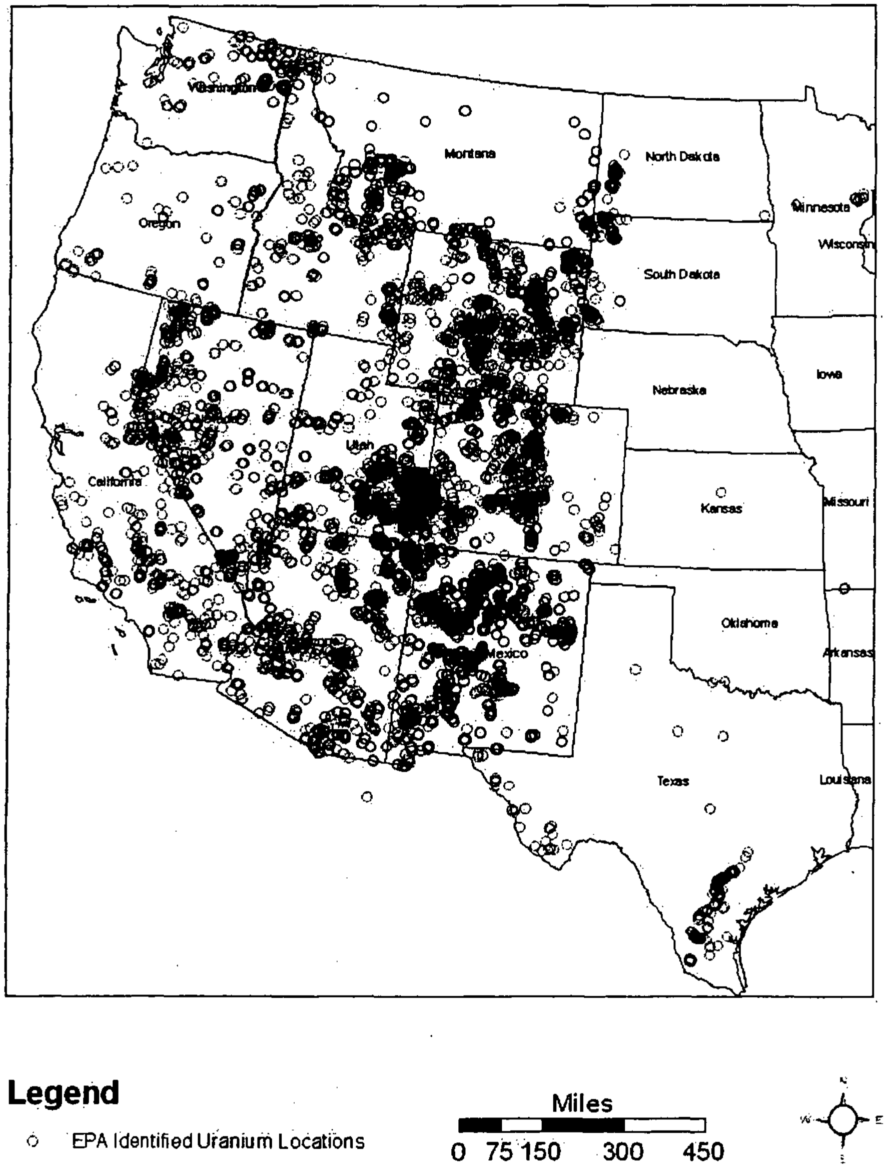

Figure 1.1-2. Major Uranium Reserves Within the United States (From Energy Information Administration, 2004)

the four specified regions of the Western United States. NRC intends that the GEIS will improve the efficiency of the licensing process by (1) providing an evaluation of the types of environmental impacts that may occur from licensing an ISL facility; (2) identifying and assessing impacts that are expected to be generic (the same or very similar) at ISL facilities with specified plant or site characteristics; and (3) identifying the scope of environmental impacts that need to be addressed in site-specific environmental reviews. The GEIS also provides information that will aid in the preparation of the site-specific environmental reviews for

ISL facilities and to help NRC maintain consistency when evaluating license applications involving the ISL process.

The availability of the GEIS does not change the basic practices and guidance that the NRC staff uses to conduct environmental reviews. In particular, the GEIS does not change the need for a detailed review of the information submitted by the applicant, nor does it change the need for conclusions in site-specific environmental assessments (EAs), SEISs, or EISs to be supported by sufficient technical bases that are transparent and traceable to supporting information. The NRC staff conducting environmental reviews is responsible for ensuring the conclusions of its environmental reviews are adequately supported by sufficient technical bases, whether that information is tiered off the GEIS or based on unique site-specific analyses.

The GEIS in no way relieves license applicants from the responsibility to adequately characterize and describe the proposed facility and site conditions in license application submittals. Information, methods, or analyses included in the GEIS that are applicable to a particular proposal could be used or referenced by license applicants provided the applicability and suitability of such referenced information is clear and its use does not significantly affect the completeness of any application.

1.2 The Proposed Federal Action

In states where NRC is the regulatory authority over the licensing of uranium milling (including the ISL process), NRC has a statutory obligation to assess each site-specific license application to ensure it complies with NRC regulations before issuing a license. The proposed federal action is to grant an application to obtain, renew, or amend a source material license for an ISL facility.

> **The Proposed Federal Action**
>
> To grant applications to obtain, renew, or amend source material licenses for an ISL facility.
>
> **Purpose for the Proposed Federal Action**
>
> To provide an option for applicants to use or licensees to continue to use ISL technology for uranium recovery.

Under NRC's environmental protection regulations at 10 CFR 51.20(b)(8), issuing a license to possess and use source material to a uranium milling facility is identified as a major federal action that requires the preparation of an EIS or a supplement to a EIS (SEIS). NRC will prepare a SEIS for new ISL facility license applications. NRC will prepare an EA, SEIS or EIS for applications to amend or renew an existing ISL facility license. The environmental review requirements for a material license are in 10 CFR Part 51. NRC's public health and safety requirements for ISL facilities are found in 10 CFR Parts 20 and 40. Parts 20, 40, and 51 require applicants to provide NRC with sufficient information to evaluate the impacts to public health and safety and the environment during the life cycle of the ISL facility. NRC then prepares safety and environmental reviews that are used by NRC officials to decide whether to grant the source material license.

In reviewing an ISL license application, NRC will use the GEIS as starting point for its site-specific environmental reviews. NRC will evaluate site-specific data and information to determine whether the applicant's proposed activities and the site characteristics are consistent with those evaluated in the GEIS. NRC will then determine which sections of the GEIS can be incorporated by reference and which impacts conclusions can be adopted in the site-specific environmental review, and whether additional data or analysis is needed to determine the environmental impacts for a specific resource area. Additionally, the GEIS provides guidance in the evaluation for certain impact analyses (e.g., cumulative impacts, environmental justice) for

which the GEIS did not make impact conclusions. No decision on whether to license an ISL facility will be made based on the GEIS alone. The licensing decision will be based, in part, on a site-specific environmental analysis that makes use of the GEIS.

1.3 Purpose and Need for the Proposed Federal Action

Commercial uranium recovery companies have approached NRC with plans to submit as many as 15 license applications for new uranium recovery facilities, as well as up to 9 applications for the restart or expansion of existing facilities in the next several years (NRC, 2009). The majority of these potential applications (perhaps 18 of the 24) would involve use of the ISL process. The companies have indicated that these new, restarted, and expanded ISL facilities would be located in Wyoming, South Dakota, Nebraska, and New Mexico.

NRC is the regulatory authority responsible for issuing a source material license for ISL facilities in those four states. 10 CFR Part 51 regulations require evaluating the environmental impacts of the ISL facility as part of the licensing process. Recognizing that the technology for ISL uranium milling is relatively standardized, that the applications may be submitted over a relatively short period of time, and that the potential ISL facilities would be located in relatively discrete regions in the western United States, NRC decided to prepare a GEIS to avoid unnecessary duplicative efforts and to identify environmental issues of concern to focus on in site-specific environmental reviews. In this way, NRC could increase the efficiency and consistency in its site-specific environmental review of license applications for ISL facilities (NRC, 2007b) and so provide an option for applicants to use and licensees to continue to use the ISL process for uranium recovery.

The purpose and need of the proposed federal action has no role in a company's decision to submit a license application to NRC for ISL uranium recovery at a particular location. From the company's perspective, the purpose of submitting an ISL license application for a new license, or renewal or amendment of an existing license, is to use or continue to use ISL technology to recover uranium at a specific site. The company could propose the use of different uranium recovery methods, including conventional milling. NRC has concluded that it is not appropriate to determine the purpose and need for a site-specific license application in the GEIS. The purpose and need for each ISL license application will be addressed in the site-specific environmental review in order to evaluate whether reasonable alternative uranium recovery methods are appropriate for the evaluation of potential environmental impacts.

1.4 Analytical Approach Used in the GEIS

1.4.1 Objectives

The GEIS serves to increase efficiency and eliminate repetitive discussions in NRC's environmental review process by identifying and evaluating environmental impacts that are generic and common to ISL uranium recovery facilities. Information from the GEIS can be summarized and incorporated by reference into the subsequent site-specific environmental review documents.

The GEIS also identifies resource areas that need site-specific information to more fully assess the environmental impacts to particular resource areas. The site-specific environmental impact analysis also will include any new or significant information necessary to evaluate the ISL facility license application.

1.4.2 Methodology

For the GEIS, NRC identified the potential environmental impacts associated with the ISL process and the resource areas that could be affected. The general methodology for doing so was to (1) describe the ISL process activities that could affect the resource, (2) identify the resource(s) that can be affected, (3) evaluate past licensing actions and associated environmental review documents and other available information, (4) assess the nature and magnitude of the potential environmental impacts to the resource(s), (5) characterize the significance of the potential impacts, and (6) identify site conditions and mitigation measures that may affect the significance.

For some types of impacts analyses (e.g., cumulative impacts, environmental justice evaluations), NRC recognized the difficulty in making determinations in the GEIS, given the location-specific nature of these analyses. For these categories, NRC collected information and conducted initial evaluations, which are documented in the GEIS. The purpose of this information gathering and initial evaluation is intended to provide background data and guidance for the site-specific analyses for these types of impact evaluations.

1.4.3 Structure of the GEIS

In this GEIS, NRC systematically evaluated the potential environmental impacts of construction, operation, aquifer restoration, and decommissioning of an ISL uranium recovery facility in four separate geographic regions of the western United States:

- **The Wyoming West Uranium Milling Region** includes portions of four Wyoming counties (Carbon, Fremont, Natrona, and Sweetwater).
- **The Wyoming East Uranium Milling Region** includes portions of eight Wyoming counties (Albany, Campbell, Carbon, Converse, Johnson, Natrona, Platte, and Weston) east of the Bighorn Mountains.
- **The Nebraska-South Dakota-Wyoming Uranium Milling Region** includes the portions of northwestern Nebraska (Dawes and Sioux Counties), western South Dakota (Custer, Fall River, Lawrence, and Pennington Counties), and the extreme eastern portion of Wyoming (Crook, Niobrara, and Weston Counties).
- **The Northwestern New Mexico Uranium Milling Region** includes McKinley County and portions of Cibola and Sandoval Counties.

1.4.3.1 Describing the ISL Process

Chapter 2 of this GEIS describes the ISL process, addressing construction, operation, aquifer restoration, and decommissioning of an ISL facility. This description is based on historical operations information from ISL facilities NRC licenses and regulates. The construction stage includes well field development and the construction of surface facilities and supporting infrastructure. Operations includes injection and production of solutions from uranium mineralization in the subsurface, as well as the process to recover the uranium from these solutions. Aquifer restoration includes activities to restore the groundwater quality in the production zone after uranium recovery is completed within a well field. Decommissioning includes the final stages of removing surface and subsurface infrastructure and reclaiming the

surface after uranium production activities at a site have been completed. Chapter 2 of the GEIS also includes a section on financial surety arrangements, where the licensee or applicant establishes a bond or other financial mechanism prior to operations to ensure that sufficient funds are available to complete aquifer restoration, decommissioning, and reclamation activities.

Site-specific license applications may not include all stages of the ISL process. For example, an applicant may propose to limit activities to well field construction, uranium mobilization, and ion exchange, and then ship the uranium-bearing resin to an existing processing plant for final processing. In this case, the applicant's license application would likely exclude the construction, operation, and decommissioning of a processing plant. NRC categorizes the ISL operations by various stages so relevant portions of the GEIS can be incorporated by reference into subsequent site-specific environmental reviews. For practical reasons, the GEIS emphasizes commonly used technologies (including some variants), but all possible variants of ISL technology are not addressed. Proposals to use technologies not addressed in the GEIS will be evaluated by NRC in a site-specific licensing review.

1.4.3.2 Describing the Affected Environment

GEIS Chapter 3 describes the affected environment for each of the four geographic regions using the environmental resource areas identified in NRC (2003b), which provides guidance to the NRC staff in conducting environmental reviews. These resource areas are

- Land use
- Transportation
- Geology and soils
- Water resources
- Ecology
- Air quality
- Noise
- Historical and cultural resource
- Visual and scenic resources
- Socioeconomic
- Public and occupational health
- Waste management

NRC staff will conduct independent, site-specific environmental reviews for each license application (see Section 1.8.3). GEIS Chapter 3 is divided into regional area discussions to facilitate using the GEIS in these site-specific reviews. Relevant sections of the regional discussions can be incorporated by reference in the site-specific environmental reviews.

1.4.3.3 Identifying Environmental Issues and Characterizing Significance

In Chapter 4, NRC evaluates the potential environmental impacts of construction, operation, aquifer restoration, and decommissioning of an ISL facility in each of the four regions. In essence, this involves conceptual placement of an ISL facility with the characteristics described in GEIS Chapter 2 within each of the four regional areas described in Chapter 3 and then describing and evaluating the significance of potential impacts in each region separately. The description for each identified potential environmental impact includes the type and magnitude of the ISL activity that would affect the environment and the attributes of the resource area that would be potentially affected.

Classifying Impact Significance (after NRC, 2003b)

- *Small Impact*: The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource considered.
- *Moderate Impact*: The environmental effects are sufficient to alter noticeably, but not destabilize, important attributes of the resource considered.
- *Large Impact*: The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource considered.

The assessment of impacts considers potential environmental consequences at each stage in an ISL facility lifecycle—construction, operation, aquifer restoration, and decommissioning/ reclamation—and presents them for each of the resource areas identified in Chapter 3.

According to the Council on Environmental Quality (CEQ), the significance of impacts is determined by examining both context and intensity (40 CFR 1508.27). Context is related to the affected region, the affected interests, and the locality, while intensity refers to the severity of the impact, which is based on a number of considerations. In describing the significance of potential impacts in this GEIS, the NRC used the significance levels identified in NUREG–1748 (NRC, 2003b) (see text box).

Considerations related to potential cumulative impacts are described in Chapter 5, and environmental justice is discussed in Chapter 6. Mitigation measures and best management practices that may reduce potential environmental impacts are identified and discussed in Chapter 7. Required monitoring programs are described in Chapter 8 and are included in the determination of significance. Chapter 9 discusses the process for NRC consultation with federal, tribal, state, and local agencies. In Chapter 10, impacts are summarized in a table for each of the four geographic regions. The structure of this GEIS is shown graphically in Figure 1.4-1.

1.5 Scope of the GEIS

The scoping process occurs early in the development of an EIS in accordance with NEPA. Scoping provides an opportunity for the public and other stakeholders to identify key issues and concerns that they believe should be addressed in the document. The NRC requirements for scoping are found at 10 CFR 51.26–29, while the general NRC approach to scoping is described in NUREG–1748 (NRC, 2003b, Section 4.2.3).

1.5.1 The GEIS Scoping Process

On July 24, 2007, NRC published in the *Federal Register* a notice of intent to prepare a GEIS to examine the potential impacts associated with ISL uranium recovery facilities (NRC, 2007b). In that notice, NRC described the scoping process for the GEIS and established a public comment period from July 24, 2007, to September 4, 2007. NRC also announced dates and times for two public scoping meetings to be held—one in Albuquerque, New Mexico, and the other in Casper, Wyoming. NRC published a revised notice of intent in the *Federal Register* on August 31, 2007, announcing a third public scoping meeting in Gallup, New Mexico, and extended the public comment period to October 8, 2007 (NRC, 2007c). Following the Gallup public meeting, NRC subsequently extended the comment period further to October 31, 2007, and finally to November 30, 2007 (NRC, 2007c). At each of the three public scoping meetings, NRC described its role and mission and reviewed NRC procedures and responsibilities. Tribal, state, and local government agencies; concerned local citizens; and other stakeholders were then invited to identify scoping issues and concerns and ask questions. Transcripts (NRC, 2008b, 2007d,e) were prepared for all three meetings and are available online at the NRC Agencywide Documents Access and Management System (ADAMS), which is accessible at www.nrc.gov or through the NRC website for the GEIS at http://www.nrc.gov/materials/uranium-recovery/ geis.html.

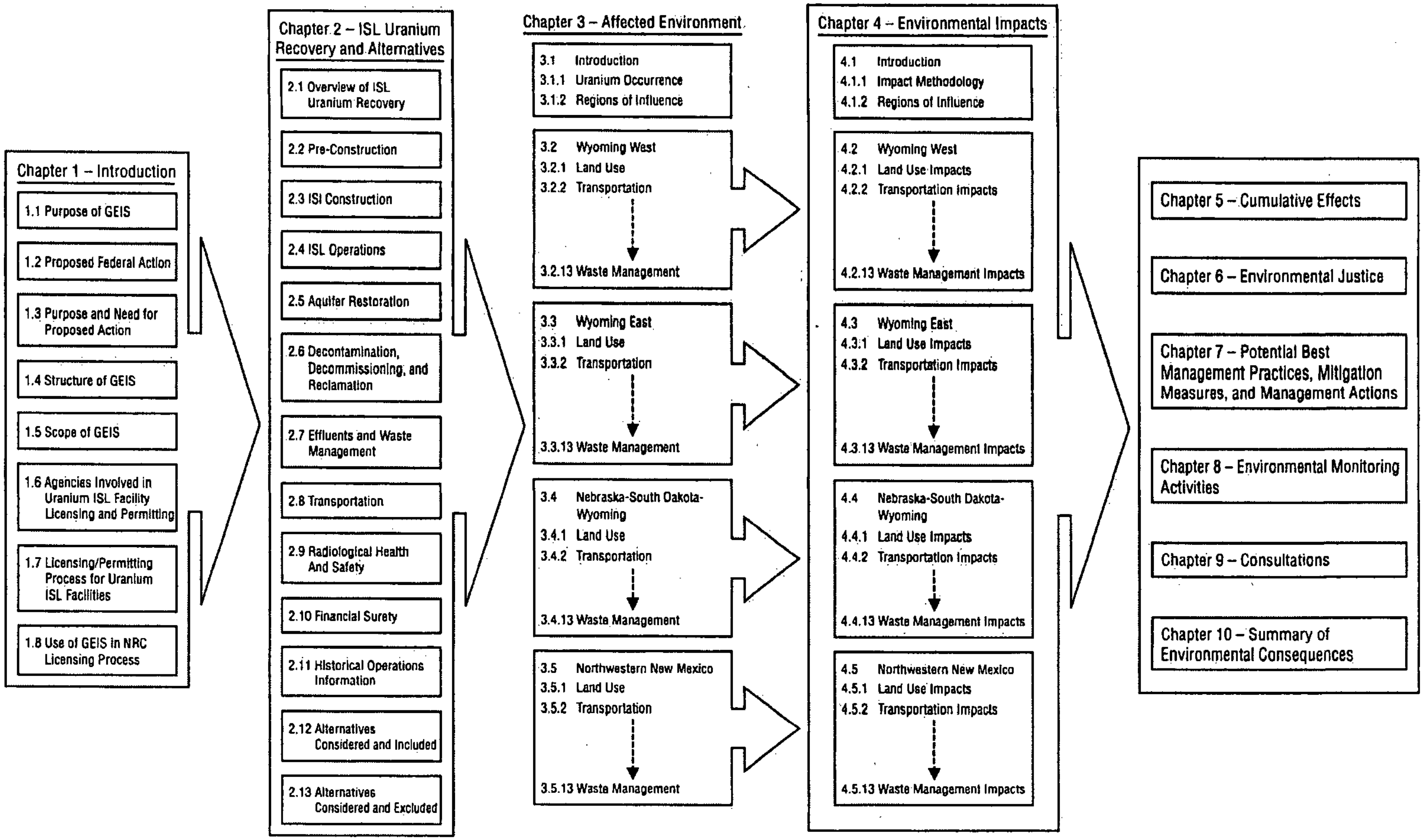

Figure 1.4-1. Structure of This GEIS

In addition to the comments received at the public meetings, NRC accepted written comments submitted either by regular mail or electronically. Using these varied methods, comments were received from approximately 1,600 entities (i.e., federal, state, and local agencies; industry organizations; public advocacy groups; and individual members of the public). A summary of comments NRC received during scoping is provided in a scoping summary report included as Appendix A to this GEIS.

1.5.2 Issues Studied in Detail

From the scoping process, NRC determined that the following issues identified by the public and other stakeholders would be addressed in the GEIS.

- **Proposed Action and Alternatives.** Scoping comments recommended clarifying the scope of the proposed action. Commenters also suggested a variety of alternatives for consideration. The proposed action is described in Section 1.2, and alternatives are described in Sections 2.12 and 2.13.

- **Applicable Statutes, Regulations, and Agencies.** Scoping comments expressed a need to clarify applicable regulations and the roles of government agencies in regulating ISL facilities. Various statutes, regulations, and implementing agencies at the federal, state, and local levels that have a role in regulating ISL facilities are identified and discussed in Section 1.6. The roles of these agencies are also described, as appropriate.

- **Purpose of the GEIS and Use in Site-Specific Licensing Reviews.** A number of scoping comments conveyed various interpretations of the purpose and intended use of the GEIS, suggesting the purpose and intended use needed to be clarified. For example, some thought the GEIS was going to be the only NEPA analysis conducted for all ISL facilities, while others thought the GEIS would eliminate or substantially degrade the rigor of NRC site-specific environmental reviews. A statement of purpose is included in Section 1.3, the NRC licensing process is described in Section 1.7.1, and the ways NRC intends to use the GEIS to evaluate environmental impacts in site-specific licensing reviews are provided in Section 1.8.

- **Opportunities for Public Involvement.** Many scoping comments reflected a perception that the GEIS would limit public involvement in ISL licensing. Some requested the opportunities for public involvement be described. Section 1.8.4 describes opportunities for public participation in the ISL licensing process.

- **Applicable Rulemaking Activities.** Some scoping comments recommended a discussion of ongoing rulemaking activities that are applicable to ISL licensing or the GEIS. The GEIS is based on the regulations in effect at the time of writing.

- **Land Use.** Concerns regarding potential land use impacts on ranching operations and livestock were raised during the scoping process. Potential impacts to existing land uses in the ISL milling regions including potential impacts to ranching, grazing, recreation, industrial, and cultural activities are discussed in Sections 4.2.1, 4.3.1, 4.4.1, and 4.5.1.

- **Transportation.** Scoping comments addressed general concerns with the safety of shipping yellowcake, road construction, fugitive dust generation, infrastructure damage, and incidental livestock kills. Potential radiological and nonradiological impacts from ISL transportation activities are discussed in Sections 4.2.2, 4.3.2, 4.4.2, and 4.5.2. Impacts from shipment of supplies, yellowcake product, and wastes associated with each phase of the ISL facility lifecycle are discussed. Normal transportation and accident conditions are considered. Potential nonradiological impacts evaluated include dust and noise generation, impacts on infrastructure such as roads, incidental livestock and wildlife kills, and changes to local traffic conditions. Potential radiological impacts considered include direct radiation and potential release of radioactive material from accidents during shipment.

- **Geology.** Scoping comments were received regarding the extent of soil disturbance and the utility of a generic analysis of geology. The GEIS describes the geology of the ISL milling regions in sufficient detail to support the evaluation of impacts to geology and soils (Sections 4.2.3, 4.3.3, 4.4.3, and 4.5.3) and groundwater (Sections 4.2.4.2, 4.3.4.2, 4.4.4.2, and 4.5.4.2) from ISL activities. GEIS Chapter 2 describes soil-disturbing activities (e.g., clearing, excavation, drilling, trenching, road construction, leaks, spills) and the magnitude of surface area disturbed at existing ISL facilities.

- **Water Resources.** A variety of water resource issues was raised in scoping comments including concerns about potential groundwater and surface water contamination, water availability and consumptive use, groundwater protection requirements, and aquifer restoration goals and techniques. The GEIS addresses potential impacts to surface waters, groundwater, and wetlands from each phase of the ISL facility lifecycle in Sections 4.2.4, 4.3.4, 4.4.4, and 4.5.4. Specific topics addressed include permitted surface water discharges, leaks and spills, groundwater excursions, consumptive water use, aquifer restoration, deep well injection, and applicable regulations. Hydrologic conditions in uranium milling regions are considered, as well as available restoration technologies and methods. The restoration of the aquifer water quality in the production zone following operations is addressed. Data from aquifer restoration efforts at ISL sites inform the analysis. Regulatory requirements and the roles of various federal, state, and local agencies regarding aquifer restoration are also discussed. Potential for groundwater impacts, in particular, is a key concern that has been historically an area of focus in NRC ISL licensing reviews.

- **Ecology.** Scoping comments on ecology raised topics regarding surface disturbance impacts on wildlife and vegetation, practices for isolating wildlife from exposure to uranium and other metals, recommended construction guidelines, habitat loss and fragmentation, and avoiding establishment of invasive species. The GEIS assesses the potential impacts to ecology in the uranium milling regions from all phases of the ISL facility lifecycle in Sections 4.2.5, 4.3.5, 4.4.5, and 4.5.5. This assessment includes consideration of potential impacts to terrestrial, aquatic, and threatened and endangered species. Specific topics addressed include evaluating ecoregions and habitat for a variety of listed species and assessing potential impacts from surface disturbances, habitat loss and fragmentation, and incidental kills. Applicable regulations and various management practices designed to protect species or mitigate potential impacts are discussed.

- **Meteorology, Climatology, and Air Quality.** Scoping comments included general environmental and safety concerns about the potential for airborne contamination, the magnitude of facility airborne releases, and applicable regulations. GEIS Sections 4.2.6, 4.3.6, 4.4.6, and 4.5.6 consider the potential impacts of all phases of the ISL facility lifecycle on local and regional air quality from both radiological and nonradiological emissions. The radiological air emissions addressed in the GEIS include radon from well fields, processing, and waste treatment operations and the potential for uranium particulate emissions from yellowcake drying operations. Nonradiological emissions addressed in the GEIS include combustion engine exhausts from trucking and well drilling operations and fugitive dusts from a variety of activities.

- **Noise.** Scoping comments on noise were limited to a statement regarding the low levels of noise ISL facilities generate. NRC recognizes that some activities in the ISL facility lifecycle can potentially generate additional noise, and impacts are evaluated in the GEIS Sections 4.2.7, 4.3.7, 4.4.7, and 4.5.7. This evaluation includes noise from well field development, uranium processing activities, and trucking activities associated with all phases of the ISL facility lifecycle.

- **Historic and Cultural.** Scoping comments were provided on historic and cultural resources including recommendations for documenting compliance with the National Historic Preservation Act requirements protecting historic properties on tribal lands, concerns about the notification process when cultural artifacts are found at an ISL facility, and opportunities for public participation regarding historic and cultural concerns. A number of individuals and organizations, primarily in New Mexico, expressed concerns on topics regarding proximity of uranium facilities to Native American communities and requested government-to-government consultations and documentation of consultations in the GEIS. The GEIS assesses potential impacts from all phases of the ISL facility lifecycle on historical and cultural resources in Sections 4.2.8, 4.3.8, 4.4.8, and 4.5.8. Local and regional historic and cultural properties and practices in ISL milling regions such as those involving Native American communities and governments are included. A description of NRC's process for consultation with Native American governments is provided in GEIS Chapter 9.

- **Visual Resources.** Scoping comments on visual resource impacts were varied. Potential impacts to visual resources in uranium milling regions from all phases of the ISL facility lifecycle are assessed in GEIS Sections 4.2.9, 4.3.9, 4.4.9, and 4.5.9. Assessments consider scenic vistas and sensitive viewsheds within uranium milling regions and ISL facility lifecycle impacts on these resources based on proximity.

- **Socioeconomics.** Scoping comments recommended evaluating social and economic impacts to local communities including job creation impacts; changes to tax base; and cumulative impacts on housing, roads, services, and labor to towns already overburdened by oil, gas, and coal development. The GEIS assesses potential impacts to socioeconomic conditions in uranium milling regions from all phases of the ISL facility lifecycle in Sections 4.2.10, 4.3.10, 4.4.10, and 4.5.10. Local and regional characteristics pertaining to demographics, income, tax structure and distribution, housing, employment, finances, education, and services are considered.

- **Public and Occupational Health.** A number of scoping comments expressed general public and worker safety concerns and more specific concerns about potential

contamination of soils, surface water, air, and groundwater; risks from radon gas and spills and from processing chemicals and resins; and emergency response and reporting. Potential impacts to public and occupational health from all phases of the ISL facility lifecycle are assessed in GEIS Sections 4.2.11, 4.3.11, 4.4.11, and 4.5.11. Both nonradiological (including chemical) and radiological effluents and releases under normal (routine) and accident conditions are assessed. Dose calculation results from previously licensed ISL facilities that include airborne uranium particulate and radon gas are provided. Hazards and risks for ISL processing chemicals are also considered. Potential soil contamination impacts from leaks and spills are discussed in Sections 4.2.3, 4.3.3, 4.4.3, and 4.5.3, and potential groundwater contamination is addressed in 4.2.4, 4.3.4, 4.4.4, and 4.5.4.

- **Waste Management.** Scoping comments expressed concerns about waste management in general and also about handling and disposal practices, deep well injection and permitted discharges, land application, disposal capacity, annual waste volumes, transportation, and applicable regulations. The GEIS considers impacts from waste management activities in all phases of the ISL facility lifecycle in Sections 4.2.12, 4.3.12, 4.4.12, and 4.5.12. Generation, handling, treatment, transportation, and final disposal of chemical, radiological, and municipal wastes are addressed. Constituents in various waste streams are identified, and volume estimates are provided.

- **Decontamination, Decommissioning, Reclamation.** A number of scoping comments expressed concerns about the site cleanup after operations end. The GEIS assesses impacts to the environment from terminating ISL operations, which include removal of facilities and equipment, disposal of waste materials, cleanup of contaminated areas, and reclamation of lands to pre-milling conditions. Decommissioning impacts are assessed for each resource area discussed in Chapter 4. Waste volume estimates by type of waste are provided, and applicable requirements are discussed.

- **Accidents.** Scoping comments requested consideration of credible accident scenarios. Potential accident conditions are assessed in various sections in the GEIS. This includes considering a range of possible accidents and off-normal operating conditions and estimating and evaluating consequences including well field leaks and spills, excursions, processing chemical spills, and ion-exchange resin and yellowcake transportation accidents.

- **Environmental Justice.** A range of opinions was provided in scoping comments on environmental justice in the GEIS. Some commenters thought it should be included in the GEIS, and others thought it should not be included. Still others provided various suggestions on how to do the analysis. GEIS Chapter 6 discusses the potential for disproportionately high and adverse environmental and health impacts on minority and low income populations from future ISL licensing in the specified uranium milling regions.

- **Cumulative Impacts.** Scoping comments on cumulative impacts offered a number of suggestions for reasonably foreseeable future actions to be included in the GEIS, including coal bed methane operations and oil and gas development. GEIS Chapter 5 describes past, present, and reasonably foreseeable future actions in the uranium milling regions and evaluates which resource areas would be potentially impacted by both ISL facilities and the types of reasonably foreseeable future actions identified in the regions. Due to the complex and site-specific nature of a cumulative impact assessment, the

GEIS provides useful information for understanding the potential for cumulative impacts when licensing future ISL facilities in the milling regions, but does not make conclusions regarding cumulative impacts for specific sites.

- **Monitoring.** Scoping comments on monitoring recommended the GEIS discuss monitoring programs designed to assess impacts from operations and waste management practices. The GEIS discusses various monitoring techniques and programs (Chapter 2, Chapter 8) used to detect radiological and nonradiological contaminants within and beyond ISL facility boundaries. This discussion includes effluent monitoring, workplace radiological monitoring, groundwater monitoring to detect potential excursions, and environmental monitoring at the facility boundary.

- **Financial Assurance.** Scoping comments recommended the GEIS discuss bonding for complete restoration of groundwater and land. Requirements and practices designed to ensure companies engaged in ISL recovery have sufficient funds to close down operations, restore aquifers, decontaminate and decommission facilities, and reclaim lands are described in GEIS Section 2.10.

1.5.3 Issues Eliminated From Detailed Study

The analyses presented in this GEIS focus on potential impacts within the four geographic regions described in Section 1.1 and illustrated in Figure 1.1-1; they are not intended to provide a detailed assessment of any specific site. Yellowcake transportation from uranium mills to the uranium hexafluoride (UF_6) conversion facility in Metropolis, Illinois, is anticipated to be by truck over existing highways. Access roads may need to be constructed to bring the yellowcake from the mill to the state and national (interstate) highway system. The existing national transportation routes are not expected to be altered. Because the environmental impacts of national transportation of yellowcake uranium have been previously analyzed, they are not studied in detail within this GEIS (NRC, 1977, 1980). These previous studies evaluated potential impacts by applying conservative risk assessment methods and assumptions to yellowcake transportation under conditions that remain applicable to present-day transportation conditions (see Section 3.2.2).

1.5.4 Issues Outside of the Scope of the GEIS

NRC has determined that comments received on topics in the following areas are outside the scope of this GEIS:

- NRC licensing process and the decision to prepare the GEIS
- General support or opposition for GEIS or uranium milling
- Requests for cooperation or agreements
- Matters that are regulated by Agreement States
- Impacts associated with conventional uranium milling past or present
- Requests for compensation for past mining impacts

- Resolution of dual regulation issues
- Consideration of human-induced climate change
- Analysis of all variations of ISL technology
- Alternative sources of uranium feed material
- Expanded cumulative impact analysis
- Energy debate
- NRC credibility

A discussion of why NRC determined that comments in these topic areas were outside the scope of the GEIS is provided in the Scoping Summary Report (Appendix A of the GEIS).

1.6 Agencies Involved in Uranium ISL Facility Licensing

A variety of federal, tribal, state, and local agencies potentially have a role in licensing and permitting an ISL uranium facility. Specific statues and regulations that may be applicable for uranium ISL facilities are detailed in Appendix B.

1.6.1 Federal Agencies

1.6.1.1 NRC

NRC responsibilities include regulating the nuclear industry in a manner that

- Protects public health and safety;
- Protects the environment; and
- Protects and safeguards materials and nuclear facilities in the interest of national security.

NRC is the federal agency with lead responsibility in licensing and regulating uranium ISL facilities through the statutory requirements of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 and the Atomic Energy Act of 1954, as amended. In part, these statutes require that NRC ensure source material, as defined in Section 11z of the Atomic Energy Act and byproduct material, as defined in Section 11e.(2) of the Atomic Energy Act, is managed to conform with applicable regulatory requirements. Congress authorized the U.S. Environmental Protection Agency (EPA) to promulgate standards of general application for 11e.(2) material in Section 275 of the Atomic Energy Act. EPA standards of general application for 11e.(2) byproduct material were established in 40 CFR Part 192. The UMTRCA and the Atomic Energy Act also require that the generally applicable standards EPA promulgates for nonradiological hazards under UMTRCA be consistent with the standards EPA promulgates under the Solid Waste Disposal Act/Resource Conservation and Recovery Act for such hazards. NRC conforming regulations are in 10 CFR Part 40, Appendix A.

NRC is the regulatory authority for ISL facilities unless NRC relinquishes its authority to a state in a written agreement. Additional information on the Agreement State Program can be found at http://www.nrc.gov/about-nrc/state-tribal/agreement-states.html.

1.6.1.2 EPA

EPA also has a role in permitting nonradiological emissions and effluents. Water quality issues are administered predominantly through underground injection control (UIC) programs and National Pollutant Discharge Elimination System (NPDES) permits. Air quality issues are addressed through National Ambient Air Quality Standards (NAAQS) and National Emission Standards for Hazardous Air Pollutants programs. These programs may be administered directly by EPA, by states and tribes granted primacy, or by joint programs between EPA and a state (EPA, 2008a–f). EPA issues permits in unauthorized states or tribal areas that are subject to exclusive federal jurisdiction.

1.6.1.3 Occupational Safety and Health Administration

The mission of the Occupational Health and Safety Administration (OSHA) is to assure the safety and health of workers in the United States, and it is the lead federal agency with responsibility for regulating the industrial safety of the work force at uranium ISL facilities. Recognizing the different agency responsibilities, NRC and OSHA have entered into a memorandum of understanding to coordinate their inspection programs and avoid duplication of effort (Occupational Safety and Health Administration, 1988). As part of this program, NRC inspectors do not perform the role of OSHA, but they may identify safety concerns or receive complaints from employees about working conditions within the areas of responsibility for OSHA, notifying the OSHA Regional Office as appropriate (Occupational Safety and Health Administration, 1988).

1.6.1.4 U.S. Department of Transportation

The U.S. Department of Transportation regulates the shipments of radiological and nonradiological hazardous materials and sets regulatory requirements for type and condition of hazardous material containers, the mechanical condition of the transportation vehicles, the training of personnel, and the routing requirements, package labels, vehicle placards, and shipping papers associated with shipments of radioactive materials. The U.S. Department of Transportation also inspects containers, storage facilities, and carrier equipment (Office of Technology Assessment, 1986).

1.6.1.5 U.S. Department of Interior, U.S. Bureau of Land Management

The U.S. Department of Interior, U.S. Bureau of Land Management (BLM) is responsible for managing the National System of Public Lands and the federal minerals underlying these lands. The BLM is also responsible for managing split estate situations where federal minerals underlie a surface that is privately held or owned by state or local government (see Section 3.1.2.2). In certain cases, the BLM also manages federal surface estates overlying privately or state-owned minerals. Operators on mining claims, including ISL uranium recovery operations, must submit a plan of operations and obtain BLM approval before beginning operations beyond those for casual use. For exploration operations disturbing less than 2 ha [5 acres], operators must submit a notice at least 15 days prior to commencing these operations. The BLM will periodically field inspect operations on plans of operation and notices. The BLM surface management program is more fully explained at 43 CFR Part 3809.

1.6.1.6 Other Federal Agencies

For individual new uranium ISL facilities proposed near or on federally managed lands, agencies such as the U.S. Forest Service or National Park Service may have jurisdiction or special expertise that leads to a role in reviewing applications for these facilities. The Bureau of Indian Affairs has responsibilities under 25 CFR Part 216 to evaluate mineral leases involving lands held in trust for Native American tribes. Other federal agencies that may be consulted on specific resource areas include the U.S. Army Corps of Engineers (wetlands), the U.S. Department of Energy Office of Legacy Management (e.g., administration of adjacent legacy sites), and the U.S. Fish and Wildlife Service (endangered and threatened species).

1.6.2 Tribal Agencies

Native American tribes do not formally have licensing authority over uranium ISL facilities. Consultations with Native American tribes would be conducted in a government-to-government relationship that exists based on applicable federal law and treaties (NRC, 2003a) during the ISL licensing process. EPA can authorize tribes to implement specific environmental permitting programs. Tribes may also have their own local laws that impact ISL facilities. Additionally, tribes may have a tribal historic preservation officer that would coordinate with NRC to support cultural resource inventories for ISL facility applications.

1.6.3 State Agencies

Individual states have regulatory authority over construction, operation, aquifer restoration, and decommissioning and reclamation at uranium ISL facilities through state-administered permitting processes. For the purposes of the GEIS, specific agencies within each state that have regulatory authority over uranium ISL facilities are identified in the following sections.

1.6.3.1 Wyoming Department of Environmental Quality

The lead agency for permitting uranium ISL facilities in Wyoming is the Wyoming Department of Environmental Quality (WDEQ). With statutory authority from the Federal Surface Mining Reclamation and Control Act and the Wyoming Environmental Quality Act, the Land Quality Division within WDEQ administers and enforces permits and licensing requirements for all operators engaged in land-disturbing activities related to mining and reclamation within Wyoming. In the context of Wyoming regulations, uranium ISL facilities are considered to be noncoal mining activities that are subject to Land Quality Division permits. Each operation must be covered by a reclamation bond to provide financial surety that reclamation requirements can be met. Through its review and consultation program, the Wyoming State Historic Preservation Office (SHPO) coordinates with NRC and WDEQ to support cultural resource inventories for uranium ISL facilities.

1.6.3.2 Nebraska Department of Environmental Quality

The Nebraska Department of Environmental Quality (NDEQ) regulates air and water quality, with statutory authority from the Nebraska Environmental Protection Act. General water quality standards and use classifications are established in Title 117 (surface water) and Title 118 (groundwater) of the Nebraska Administrative Code (NDEQ, 2006a,b). The Nebraska NPDES program is described in Title 119 (NDEQ, 2005), and the regulatory requirements for underground injection, mineral production wells, and waste disposal wells related to ISL uranium recovery are governed by UIC requirements in Title 122 of the Nebraska Administrative

Code (NDEQ, 2002a). The Nebraska SHPO is a division of the Nebraska State Historical Society. The Nebraska SHPO manages historic preservation programs within the state, which includes developing and maintaining a statewide historic preservation plan and providing supporting planning programs for other state agencies.

1.6.3.3 South Dakota Department of Environment and Natural Resources

With renewed interest in uranium resources in South Dakota, the 2006 State Legislature passed legislation to fill gaps in the existing state laws that govern uranium exploration and recovery. This legislation authorized the South Dakota Board of Minerals and Environment to develop rules to issue state permits and licensing requirements to ISL facilities under the South Dakota Mined Land Reclamation Act (South Dakota Codified Law 45–6B). The final rules were adopted in April 2007 (South Dakota Department of Environment and Natural Resources, 2007a). The South Dakota SHPO is a program of the South Dakota State Historical Society within the Department of Tourism and State Development. The South Dakota SHPO manages historic preservation programs within the state and coordinates and plans historic preservation efforts across the state.

1.6.3.4 New Mexico Environment Department

The New Mexico Environment Department was established under the provisions set forth in the Department of the Environment Act by the 40th State Legislature, enacted July 1, 1991 (Laws of 1991, Chapter 25). The New Mexico Environment Department, with statutory authority from the New Mexico Oil and Gas Act and the New Mexico Water Quality Act, has UIC permitting authority over uranium ISL facilities. The New Mexico SHPO is part of the Historic Preservation Division within the New Mexico Department of Cultural Affairs. The New Mexico SHPO administers historic preservation programs within the state and provides information and technical assistance to state agencies, local governments, and private owners.

1.7 Licensing and Permitting Process for a Uranium ISL Facility

As noted in Section 1.6, NRC has statutory authority through the Atomic Energy Act and UMTRCA to regulate uranium ISL facilities. In addition to obtaining an NRC license, uranium ISL facilities must obtain the necessary permits from the appropriate federal, tribal, and state agencies. The NRC licensing process and other potential federal, tribal, and state permitting processes are briefly discussed in this section to provide a basic understanding of potential permitting requirements for uranium ISL facilities in the four geographic regions in Figure 1.1-1. This is not intended to be an exhaustive description of all permits that may be necessary for a specific facility.

1.7.1 The NRC Licensing Process

The general NRC process for licensing facilities is described in NRC (2003b) and illustrated in Figure 1.7-1. This process has been modified for ISL facilities. After receiving a license application for either a new facility or the renewal or amendment of an existing facility license, NRC conducts an acceptance review to determine whether the application is complete enough

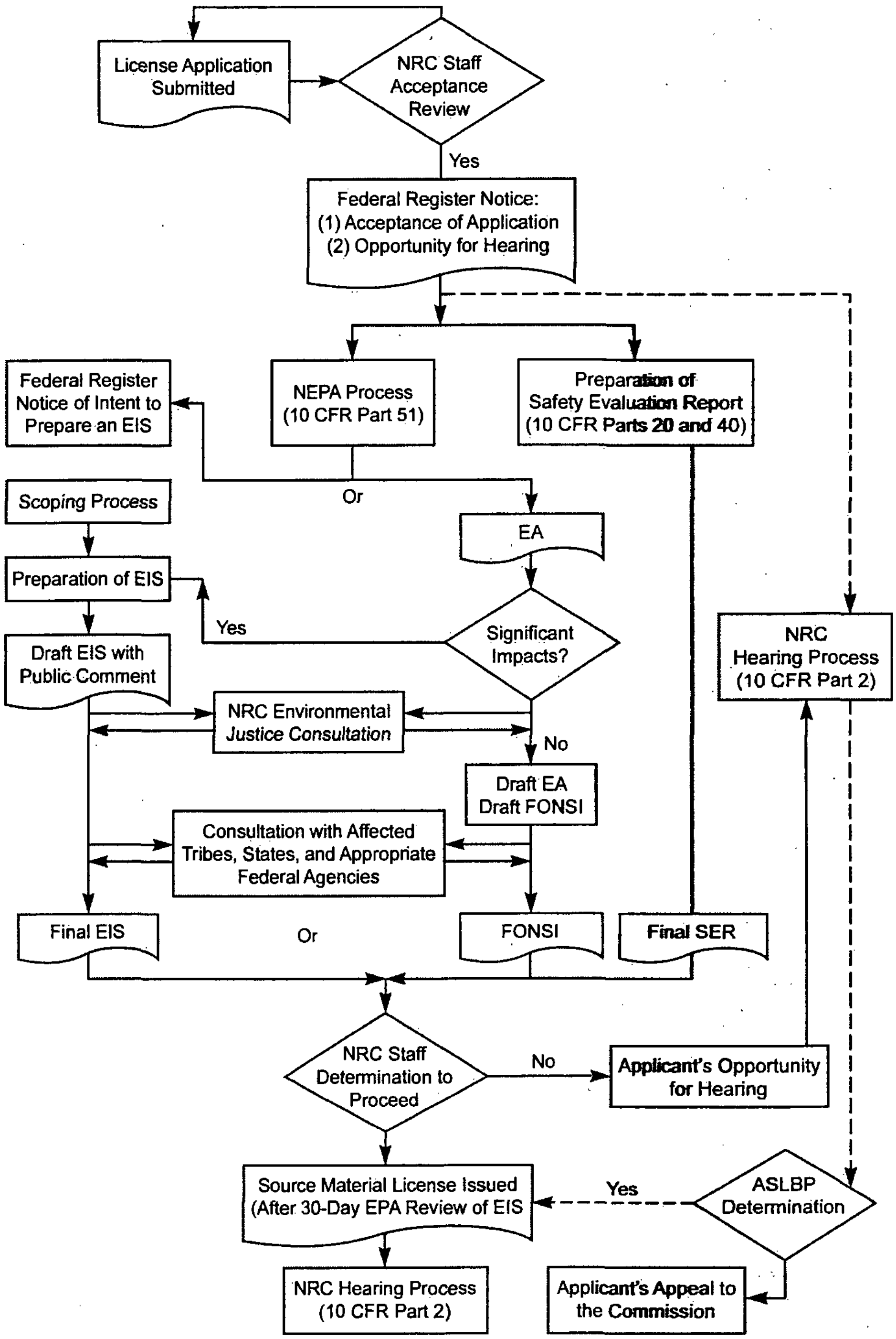

Figure 1.7-1. General Flow Diagram of the NRC Licensing Process for 10 CFR Part 40 Licenses (From NRC, 2003a). ASLBP–Atomic Safety Licensing Board Panel; EA–Environmental Assessment; EIS–Environmental Impact Statement; FONSI–Finding of No Significant Impact; NEPA–National Environmental Policy Act; SER–Safety Evaluation Report.

to support more detailed technical review. If NRC determines that a new license or license renewal application is acceptable for detailed review, it will formally docket the application and publish a Notice of Availability of the application in the *Federal Register*. For license amendment applications, the results of NRC's acceptance review can be documented in a letter to the licensee. NRC's detailed technical review of an application (either for a new license or for the renewal or amendment of an existing license) is composed of a safety review and an environmental review. NRC conducts the safety review to assess compliance with the regulatory requirements of 10 CFR Part 20 and 10 CFR Part 40, Appendix A. In parallel with the safety review, the NRC staff is required under NEPA to conduct an environmental review for each license application. The NRC environmental protection regulations applicable to licensing actions are found in 10 CFR Part 51. As appropriate, the NRC staff may propose license conditions to ensure that specific features of a given site are taken into account in protecting worker and public health and safety and the environment. The NRC hearing process (10 CFR Part 2) applies to NRC licensing actions and offers stakeholders a separate opportunity to raise concerns with the proposed action during the licensing process.

If a new license is issued or a license amendment granted, NRC ensures that the licensee complies with the conditions of its NRC license and the applicable regulations through an inspection program managed out of one of its four regional offices. The NRC Region IV office in Arlington, Texas, would manage inspection programs for ISL uranium recovery facilities located in each of the four regions analyzed in this GEIS.

NRC inspections are guided by the NRC inspection manual, which includes detailed procedures for various types of inspections. Examples of topics addressed by ISL facility inspections include construction, management organization and controls, training of personnel, radiation protection programs, facilities and equipment, environmental protection, financial assurance, transportation of radioactive materials, radioactive waste management, efforts to maintain effluents as low as is reasonably achievable (ALARA), emergency preparedness, decommissioning, and security of nuclear materials. Inspections occur at least annually, but NRC inspection staff can adjust the inspection frequency based on a number of variables, including licensee performance. Inspections can be announced or unannounced. In addition to inspections, the NRC staff reviews the licensee-submitted semiannual effluent and environmental monitoring reports and takes the necessary actions to respond to reported incidents at ISL facilities (e.g., spills, excursions, and other reportable events).

The inspection process may identify violations that are subject to enforcement actions by the agency. The NRC enforcement policy endeavors to deter non-compliances by emphasizing the importance of compliance with NRC requirements. The enforcement policy also encourages prompt identification and comprehensive correction of violations. Accordingly, licensees, contractors, and their employees who do not achieve the high standard of compliance expected by NRC, are subject to enforcement sanctions. As part of the enforcement process, NRC considers the recent performance history and the number and severity of violations for a given licensee. Further, licensees, employees, and contractors who engage in deliberate misconduct or who deliberately submit incomplete or inaccurate information to NRC are subject to significant enforcement sanctions, including civil penalties and legally binding orders.

1.7.2 EPA Permitting

Under environmental laws such as the Clean Water Act, the Safe Drinking Water Act, and the Clean Air Act, EPA has statutory authority to regulate activities that may affect the environment. EPA permitting that is most relevant for uranium ISL facilities is related to underground injection of the leaching solution (i.e., the lixiviant) and liquid effluents, surface discharge of treated waters and industrial and construction stormwaters, and air quality.

1.7.2.1 Water Resources

Under the Safe Drinking Water Act, EPA was granted primary authority to regulate underground injection and protect current and future sources of drinking water. Underground injection is broadly defined as the process of placing fluids underground through wells or other similar conveyance systems. EPA implements this responsibility through its UIC program (EPA, 2008a). EPA may administer the programs directly for states or tribal lands or jointly with the state or tribal government. Alternatively, EPA may also authorize individual states or tribes to administer the UIC programs in accordance with EPA regulations. Currently, Wyoming, Nebraska, and New Mexico are authorized states. South Dakota administers the UIC program jointly with EPA, with the state administering the program for UIC Class II permits (EPA, 2008b).

Native American tribes can follow the same rules as states for obtaining authorization (40 CFR Part 145) if they are considered a "Federally Recognized Tribe" and have been designated for "Treatment Similar to a State." Tribes that want to enforce the federal UIC requirements must submit an application for approval of their program to EPA. As of this writing (April 2009), EPA has approved applications from two tribes (the Fort Peck Assiniboine and Sioux Tribes in Montana and the Navajo Nation) to implement UIC programs for Class II (oil and gas-related) injection wells. In the absence of tribal authorization, EPA can directly administer the UIC program in tribal areas even if they are located in a State with an approved UIC program.

UIC Permitting (from EPA, 2008a)

In the four regions covered in this GEIS, the state implements UIC permitting for all five UIC permit classes for Wyoming, Nebraska, and New Mexico and for UIC Class II for South Dakota. Classes I and III are most applicable to uranium ISL facility operations.

- *Aquifer Exemption.* UIC criteria for exemption of an aquifer that might otherwise be defined as an underground source of drinking water are found at 40 CFR 146.4. These criteria include whether the aquifer is currently a source of drinking water and whether the water quality is such that it would be economically or technologically impractical to use the water to supply a public water system.
- *Industrial and Municipal Waste Disposal Wells (UIC Class I).* This permit class governs deep disposal of industrial, commercial, or municipal waste below the deepest usable aquifer. This type of injection uses wells and requires applied pressure. It includes all wells that dispose of waste on a commercial basis, even if the waste would be otherwise eligible for disposal into a Class II well (e.g., WDEQ, 2005, 1993). For uranium ISL facilities, this type of UIC permit is necessary to use deep well injection for waste disposal.
- *Mining Wells (UIC Class III).* These permits govern injection wells drilled to recover minerals. They includes experimental technology wells; underground coal gasification wells; and wells for the *in-situ* recovery of materials such as copper, uranium, and trona. For uranium ISL facilities, this type of UIC permit covers wells that inject the lixiviant into the uranium mineralization.
- *Shallow Nonhazardous Injection Wells (UIC Class V).* This permit class covers all injection wells not included in Classes I-IV. In general, Class V wells inject nonhazardous fluids into or above underground sources of drinking water and are typically shallow, onsite disposal systems. However, some deep Class V wells inject below underground sources of drinking water.

Unless authorized by rule or by permit, any underground injection is unlawful and violates the Safe Drinking Water Act and UIC regulations. Before an NRC-licensed uranium ISL facility can

begin operations at any project site, the licensee must obtain the necessary UIC authorizations. These will include (1) an aquifer exemption (also called exempting the aquifer as an underground source of drinking water) for the aquifer or portion of the aquifer where the uranium mobilization and recovery will occur and (2) a Class III UIC permit to operate injection wells. In addition, if deep well injection will be used to dispose of certain liquid wastes, the licensee will need to obtain a Class I UIC permit.

Under the provisions of the Clean Water Act, the NPDES program regulates discharges of pollutants from a point source into surface water of the United States. Operators of a point source discharge must obtain an NPDES discharge permit (EPA, 2008d). The permits contain limitations and conditions that are intended to protect surface water quality. Permits can cover either operational (industrial stormwater and process water including dewatering, produced water, and treated wastewater) or construction phases. Construction stormwater NPDES authorizations are applied for and issued annually under a general permit based on projected construction activities. For a construction stormwater authorization, a notice of intent is filed before construction activities begin.

As with the UIC program, EPA either directly administers the NPDES permitting program or may authorize the permitting authority to a state or tribe (EPA, 2008e). State-implemented NPDES programs (covering commercial industrial facilities such as ISL uranium mills) are authorized in Wyoming, Nebraska, and South Dakota. EPA directly administers the NPDES program in New Mexico and in Indian Country (EPA, 2008f).

1.7.2.2 Air Quality

EPA was given the primary responsibility to set standards and oversee the Clean Air Act. Similar to water protection programs, EPA may authorize the states, tribes, and local agencies to prevent and control air pollution. Under the Clean Air Act, EPA developed the following standards:

- National Primary and Secondary Ambient Air Quality Standards in 40 CFR Part 50
- National Emission Standards for Hazardous Air Pollutants in 40 CFR Part 40
- Prevention of Significant Deterioration in 40 CFR Part 52

As described in 40 CFR Part 51, Requirements for Preparation, Adoption, and Submittal of Implementation Plans, states must develop state implementation plans consisting of regulations, programs, and policies that describe how each state will control air pollution under the Clean Air Act. Agencies must obtain EPA approval for these implementation plans. The permitting process is a mechanism agencies use to put the implementation plans into effect. EPA's Tribal Authority Rule gives tribes the ability to (1) develop air quality management programs, (2) write air pollution reduction rules, and (3) implement and enforce these rules. Similar to the states, tribes must obtain EPA approval for these implementation plans.

The Clean Air Act permitting process is divided into two programs: the New Source Review program (preconstruction) and the Title V program (operation). NRC is not the regulatory authority for Clean Air Act permitting. Permitting authorities are identified in Table 1.7-1. The New Source Review requires stationary air pollution sources to obtain permits prior to construction. This is commonly referred to as construction or preconstruction permitting.

Three types of New Source Review permits exist: (1) Prevention of Significant Deterioration, (2) nonattainment New Source Review, and (3) minor New Source Review. In attainment areas (i.e., those areas where air quality meets the NAAQS), Prevention of Significant Deterioration permits are required for major stationary pollutant sources that are new or making major modifications. The threshold for classification as a major source in an attainment area is either 90.7 or 227 metric tons [100 to 250 short tons] of a regulated pollutant, depending on the source. In nonattainment areas, the nonattainment New Source Review permits are required for major stationary pollutant sources that are new or making major modifications. The threshold for classification as a major source in a nonattainment area is generally 90.7 metric tons [100 short tons] of a regulated pollutant. This threshold can be lower for areas with more serious nonattainment problems. The minor New Source Review permits are for sources that do not require Prevention of Significant Deterioration or nonattainment New Source Review permits. A minor New Source Review permit is intended to support the Prevention of Significant Deterioration and nonattainment New Source Review programs by implementing permit conditions as needed that limit emissions from sources not covered by those two programs. The factors that determine which permit applies to a particular proposed ISL facility are the NAAQS compliance status and whether the facility was classified as a major or minor source. Specific requirements would be determined by the appropriate regulatory authority on a site-specific basis.

Operating permits, called Title V permits, are required for most large sources and some smaller sources of air pollution. State or local agencies issue most Title V permits. In general, ISL facilities do not meet the emissions thresholds that invoke Title V requirements or require operating permits. However, to the extent that an ISL facility would meet the general requirements identified for EPA regulations at 40 CFR Part 70 and 71 {e.g., by exceeding either a general emissions threshold of 90.7 metric tons [100 short tons] for any air pollutant, lower thresholds for areas that are in nonattainment with air quality standards, or major source thresholds for hazardous air pollutants}, the licensee or applicant would need to obtain the necessary Title V permit before beginning operations.

Table 1.7-1. New Source Review Permit Summary Information for Nebraska, New Mexico, South Dakota, and Wyoming*

Area	Permitting Authority	Regulations
Nebraska†	State and local agencies	State Implementation Plan
New Mexico†	State and local agencies	State Implementation Plan
South Dakota†	State agency	State Implementation Plan‡
Wyoming†	State agency	State Implementation Plan
Indian country (all four states)	Appropriate U.S. Environmental Protection Agency regional office	40 CFR 52.21

*Modified from U.S. Environmental Protection Agency. "Prevention of Significant Deterioration (PSD) Permit Program Status: February 2009." 2009. <http://www.epa.gov/nsr/where.html> (29 April 2009).
†Except for Indian country.
‡Except for Prevention of Significant Deterioration permitting that is regulated by 40 CFR 52.21.

1.7.3 Other Federal Agencies

NRC and the U.S. Department of Transportation jointly regulate the safety of radioactive material shipments. The NRC regulations to transport radiological materials such as yellowcake and uranium-loaded resins are established in 10 CFR Part 71. For example, refined yellowcake is packaged and shipped in 208-L [55-gal], 18-gauge steel drums holding an average of 430 kg [950 lb]. The U.S. Department of Transportation classifies this as Type A packaging (49 CFR Parts 171–189 and 10 CFR Part 71).

Because the federal government manages a portion of the land in the four geographic regions discussed in this GEIS, BLM may control surface access at uranium ISL sites proposed for federal lands. BLM administers grazing on public ranchlands through field offices located in each state. The licensee must obtain the necessary mineral rights and environmental clearances from BLM for surface disturbances and approval for temporary occupancy. BLM requires (per 43 CFR 3809) the ISL licensee or applicant to submit a plan of operations. The BLM-required information can be (and usually is) included as part of the applicant's state-required forms/applications. Unlike NRC, BLM considers all mineral recovery to be mining. BLM regulates land use for operations proposed on BLM land and where the surface rights are privately owned and the mineral rights are under federal jurisdiction.

1.7.4 Tribal Agencies

Like states, Native American tribes can be authorized to implement the EPA Clean Water Act and Clean Air Act programs and can have their own permitting authority (e.g., Navajo Nation Environmental Protection Agency). This is discussed further in Sections 1.7.2.1 and 1.7.2.2. Additionally, NRC has a responsibility to consult with tribes; the process for doing so is discussed in GEIS Chapter 9.

At least one tribe, the Navajo Nation, has enacted tribal legislation that prohibits all uranium processing activities. On April 29, 2005, Navajo Nation President Joe Shirley, Jr. signed the Diné Natural Resources Protection Act of 2005. The Navajo ban on uranium milling and processing presents a number of complex legal and policy issues, including whether a particular site falls under the definition of "Navajo land" in the Diné Natural Resources Protection Act of 2005.

The NRC approach to these types of jurisdictional issues has been to fulfill NRC statutory mandates to evaluate license applications and determine whether a particular application complies with the Atomic Energy Act and NRC regulations. At the same time, NRC recognizes that other governmental entities, in this case the Navajo Nation, may also have jurisdiction over some issues. The Commission acknowledges and recognizes that the Navajo Nation has certain sovereign powers under federal law. In general, although a license applicant may demonstrate that it meets the Atomic Energy Act and NRC regulations and thereby receives an NRC license, the applicant may nonetheless need to address other applicable requirements and obtain other necessary permits from appropriate regulatory authorities to go forward with its project.

1.7.5 State Agencies

The following sections briefly describe relevant state permitting requirements for Wyoming, Nebraska, South Dakota, and New Mexico.

1.7.5.1 Wyoming

WDEQ provides general guidance on Wyoming regulatory requirements for ISL operations in several reports (WDEQ, 2000a, 2005). WDEQ issues state permits relevant to ISL uranium recovery operations under Title 35, Chapter 11, of the Wyoming Environmental Quality Act. Most of these permits are related to water supply and air and water quality issues and include aquifer exemption; UIC Class I, III, and V permits; and NPDES permits (WDEQ, 2007, 2005, 2001, 2000b, 1993, 1984). In Wyoming, injection of fluids at an ISL mine unit for uranium production operations requires UIC Class III wells. Injection of ISL waste for disposal underground requires either a Class I or Class V UIC permit. In addition, the WDEQ Land Quality Division issues permits to mine for noncoal resources and for *in-situ* recovery operations (WDEQ, 2003, 2000a). These permits identify site-specific requirements related to establishing baseline conditions (e.g., water, soils, vegetation, cultural values) and establishing reclamation bonds based on estimated site-specific costs. The WDEQ Land Quality Division holds joint bonds with BLM for exploration and mining on BLM lands. A memorandum of understanding exists between WDEQ Land Quality Division and BLM for surface management of locatable mineral operations. Wyoming also implements the NPDES program regarding discharges to surface waters. With regard to air quality permitting, WDEQ establishes the NAAQS requirements (WDEQ, 2006) (see Table 1.7-1). In addition, the Wyoming State Land Use Planning Act established a State Land Use Commission to govern leases, easements, and temporary uses of state lands. The state also regulates drilling and well spacing and requires drilling permits for wells, regardless of land ownership.

1.7.5.2 Nebraska

The regulations established in Title 122 of the Nebraska Administrative Code ensure proper well construction and regulate the injection of fluids containing potential contaminants into, above, or below underground sources of drinking water. NDEQ must approve injection wells, which must be operated and managed in accordance with the applicable NDEQ regulations. NDEQ issues and reviews UIC permits, conducts inspections, and performs compliance reviews for wells that inject fluids into the subsurface to ensure that injection activities comply with state and federal regulations and that groundwater is protected from potential contamination sources. Similar to WDEQ in Wyoming, NDEQ has authority over and manages Class I, III, and V wells in Nebraska. Injection wells not included in the other specific classes are considered Class V wells. In Nebraska, regulations adopted in 2002 prohibit a number of Class V well types, including radioactive waste disposal wells. The NDEQ UIC program is currently closing existing waste disposal systems that fall into these prohibited types. EPA reviews and approves the aquifer exemption portion of the NDEQ UIC program (40 CFR 146.4). Nebraska also implements the NPDES program regarding discharges to surface waters. With regard to air quality permitting, NDEQ establishes the ambient air quality standards through a state-administered NAAQS program described in Title 129 of the Nebraska administrative code (NDEQ, 2002b).

1.7.5.3 South Dakota

As described in Section 1.6.3.3, recent legislation passed in South Dakota establishes permitting requirements for uranium recovery activities. Activities covered under these permits include sinking shafts, tunneling, and drilling test holes, cuts, or other works to extract samples (including bulk samples) to confirm the commercial grade of a uranium deposit before mining operations or test facility development begins. Uranium milling, including ISL uranium recovery, requires a state mine permit issued under South Dakota Codified Law 45-6B and South Dakota

Administrative Rule Chapter 74:29. The Board of Minerals and Environment evaluates permit applications for uranium exploration in South Dakota (South Dakota Department of Environment and Natural Resources, 2007a, 2006). South Dakota implements the NPDES program regarding discharges to surface waters. The South Dakota Department of Environmental and Natural Resources is the air quality permitting authority through its NAAQS program (South Dakota Department of Environment and Natural Resources, 2007b).

1.7.5.4 New Mexico

Water quality standards in New Mexico are established in accordance with Water Quality Control Commission regulations in Title 20, Chapter 6, Part 2 of the New Mexico Administrative Code. The New Mexico Environment Department administers the state's UIC programs. For ISL uranium milling operations on state-regulated lands in New Mexico, an operator must obtain a Class III injection well permit and an aquifer exemption from EPA requiring aquifer cleanup and monitoring to protect surrounding underground sources of drinking water. For operations outside Indian lands in New Mexico, operators need to obtain the Class III injection well permit and a temporary aquifer designation from the New Mexico Environment Department, subject to EPA review and approval. EPA directly administers the NPDES program for surface water discharges in New Mexico. With regard to air quality permitting, the New Mexico Environment Department is the permitting authority through its NAAQS program (New Mexico Environmental Department, 2002).

1.8 Use of the GEIS in the NRC Licensing Process

NRC plans to use the GEIS to fulfill the requirement at 10 CFR 51.20(b)(8) for the preparation of an EIS or supplement to an EIS for the issuance of a source material license for an ISL uranium milling facility. NRC will use the GEIS to prepare a supplemental EIS (SEIS), incorporating by reference the relevant sections of the GEIS, and supplementing the GEIS evaluations with site-specific analysis as necessary for the issuance of a new ISL license. Additionally, NRC will use the GEIS in its review of applications to renew or amend existing ISL licenses.

As an independent federal agency, NRC uses other CEQ regulations as guidance for its NEPA reviews. In this case, CEQ's regulation at 40 CFR 1502.4 allows, and in some cases requires, preparation of EISs for "broad federal actions." In preparing EISs on broad actions, the CEQ offers different approaches for agencies to take in their evaluations. These include evaluating proposals (1) geographically (i.e., those actions occurring in the same general location) and (2) generically (i.e., those actions which have relevant similarities, such as common timing, impacts, alternatives, methods or implementation, media, or subject matter).

Another concept associated with the preparation of "broad action" EISs is tiering. Tiering (defined in 40 CFR 1508.28) is a procedure by which more specific or more narrowly focused environmental documents can be prepared without duplicating relevant parts of previously prepared, more general, or broader documents. The more specific environmental document incorporates by reference the general discussions and analyses from the existing broader document and concentrates on the issues and impacts of the project that are not specifically covered in the broader document. NRC environmental regulations, in discussing the format for presentation of material in EISs, note that the techniques of tiering and incorporation by reference described respectively in CEQ's NEPA regulations may be used as appropriate to help present issues, eliminate repetition, or reduce the size of the EIS (see 10 CFR Part 51, Subpart A, Appendix A). NRC plans to use tiering and incorporation by reference in making use of the GEIS for environmental reviews of site-specific ISL license applications.

The following discussion provides a more detailed description of how the NRC staff will use the GEIS as part of the staff's environmental reviews for new ISL license applications and for applications to renew or amend existing licenses. The discussion is also applicable to NRC's review of applications to renew or amend existing NRC ISL licenses.

1.8.1 Applicant or Licensee Environmental Report

License applicants must submit an environmental report to support their application for an NRC license to possess and use source material for ISL uranium milling. NRC regulations at 10 CFR 51.45 list the general content of the environmental report to include, among other things

- A description of the proposed action
- A statement of its purposes
- A description of the environment affected
- Consideration of the impact of the proposed action on the environment
- Identification of any adverse environmental effects that cannot be avoided
- Discussion of alternatives to the proposed action

To help potential uranium milling license applicants develop their environmental reports, NRC provides additional guidance in

- Regulatory Guide 3.46, "Standard Format and Content of License Applications, Including Environmental Reports, for *In-Situ* Uranium Solution Mining" (NRC, 1982)

- NUREG–1569, "Standard Review Plan for *In-Situ* Leach Uranium Extraction License Applications" (NRC, 2003a)

- NUREG–1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs" (NRC, 2003b)

1.8.2 Acceptance Review of the License Application and Environmental Report

After receiving a new license or license renewal application and accompanying environmental report, the NRC staff first reviews the application and environmental report for completeness. This initial "acceptance review" ensures that the application and environmental report are sufficiently comprehensive and address all relevant aspects of the applicant's proposed actions. When the NRC staff determines that the application is acceptable to warrant detailed technical review, the application is officially docketed in accordance with NRC's regulations at 10 CFR Part 2. Then NRC publishes in the *Federal Register* notice of the public availability of the application and accompanying notice of opportunity for hearing on the application.

In its subsequent detailed technical review of an ISL license application, the NRC staff analyzes the health and safety impacts (documented in a Safety Evaluation Report) and the potential environmental impacts of the proposed action (discussed in a separate environmental review document—a SEIS for issuance of a new ISL license, or EA, SEIS or EIS for license renewals or amendments).

1.8.3 NRC's Site-Specific Environmental Review

To meet its NEPA obligations related to a site-specific license application, the NRC staff will conduct an independent, detailed, comprehensive evaluation of the potential environmental impacts of the applicant's proposed action for construction, operation, aquifer restoration, and decommissioning of an ISL facility. This site-specific evaluation will make use of the discussion and conclusions reached in the GEIS to the extent applicable to the specific site.

As the basis for its independent evaluation, the NRC staff will rely initially on the applicant's detailed environmental report for information on the proposed action. The applicant's environmental report would include detailed information about the potential ISL facility location, the extent of proposed operations and schedule, and the surrounding local and regional affected environment. The NRC staff will confirm important attributes of these descriptions through visits to the proposed site location and vicinity, independent research activities, and consultations with appropriate federal, tribal, state, and/or local agencies. Additionally, the NRC staff typically requests additional information from the applicant. These requests require the applicant to provide the information and data the NRC staff considers necessary to determine the potential environmental impacts.

> **The NRC Safety Review**
>
> In addition to meeting its responsibilities under the Atomic Energy Act of 1954, as amended, NRC prepares a Safety Evaluation Report to analyze the safety of the proposed action and assess its compliance with applicable NRC regulations.
>
> The safety and environmental reviews are conducted in parallel (Figure 1.7-1). Although there is some overlap between the content of a Safety Evaluation Report and the environmental review document, the intent of the documents is different.
>
> To aid in the decision process, the environmental review document summarizes the more detailed analyses included in the Safety Evaluation Report. For example, the environmental review document would not address how accidents are prevented but the environmental impacts that would result if an accident occurred.
>
> Much of the information describing the affected environment in the environmental review document also is applicable to the Safety Evaluation Report (e.g., demographics, geology, and meteorology) (NRC, 2003b).

The NRC staff will focus on the applicant's assessment of potential environmental impacts from the proposed action and the identified alternatives. In its site-specific environmental review document, NRC will evaluate a reasonable range of alternatives to the applicant's proposal, including the "no-action" alternative. This range of alternatives may include alternatives not identified by the applicant, as well as those outside NRC's jurisdiction. The NRC staff will independently evaluate the applicant's analysis of the potential impacts to each resource area identified in NRC (2003b) (e.g., air quality, transportation, groundwater). As needed, the NRC staff will independently confirm and verify essential aspects of the analysis. Confirmatory analyses could involve the use of computer codes and other verification techniques.

The GEIS is intended to improve the efficiency of the licensing process by (1) providing an evaluation of the types of environmental impacts that may occur from ISL uranium milling facilities, (2) identifying and assessing impacts that are expected to be generic (the same or similar) at all ISL facilities (or those with specified facility or site characteristics), and (3) identifying the scope of environmental impacts that need to be addressed in site-specific environmental reviews. The GEIS also provides information that will aid in the preparation of site-specific environmental documents.

First, the NRC staff will compare the applicant's description of the proposed facility, ISL process, and affected environment to those in the GEIS. The NRC staff will then summarize and

incorporate by reference the relevant sections of the GEIS into the site-specific environmental review document. Secondly, the NRC staff will use the GEIS to help determine the significance of site-specific environmental impacts. The GEIS provides criteria for each environmental resource area to help determine the significance level of potential impacts (e.g., SMALL, MODERATE, or LARGE). The NRC staff will apply these criteria to site-specific conditions to determine the significance of potential impacts. Finally, the NRC staff will compare the conditions of the proposed site and activities under review to the conditions and aspects identified and discussed in the GEIS to see whether the conclusions for the environmental impact to a particular resource area can be adopted in the site-specific environmental review document. The NRC staff may determine that the GEIS conclusions for a specific resource area can be adopted in full, only in part, or not at all. The determination of the extent to which the GEIS conclusions can be adopted will be discussed in detail in the site-specific review, including the supporting information and data that form the basis for that determination. Additionally, the NRC staff will also determine the significance of environmental impacts for resource areas where the GEIS conclusions can be adopted only in part or not at all. The NRC staff will document the basis for that determination in the site-specific evaluation. The site-specific review will incorporate by reference and adopt significance conclusions from the GEIS, as appropriate. This process of using the GEIS in site-specific environmental reviews is consistent with the concept of tiering, discussed previously (see Section 1.8).

1.8.4 Public Participation Activities

As stated in Section 1.8.2, upon acceptance of a license application for detailed technical review, NRC publishes in the *Federal Register* a notice of opportunity for hearing on the application. Individuals or entities that may be affected by the potential issuance of the site-specific ISL license may request a hearing under the NRC formal hearing process. 10 CFR Part 2 provides the requirements that must be met to be granted a hearing.

As discussed previously, the NRC staff will prepare an environmental review document in support of its review of ISL-related licensing actions (i.e., new license, renewal or amendment). For new ISL license applications, the NRC staff will prepare a SEIS. The NRC staff will follow the public participation procedures outlined in 10 CFR Part 51, which can include requests for public input on the scope of the SEIS and for public comment on the draft SEIS.

Before taking a licensing action on a licensee's proposal to amend or renew its existing NRC license, the NRC may prepare an environmental assessment and if so, also may make the draft EA and the accompanying draft Finding of No Significant Impact (FONSI) available for public comment. The decision to do so would take into account the provisions in 10 CFR 51.33 concerning the similarity of the proposed action to actions normally requiring preparation of an EIS and the precedent-setting nature of the proposed action. Additionally, NRC may consider the level of public interest and the contentious nature of the proposed action in determining whether to publish a draft EA/FONSI for public comment. The NRC staff would address public comments received on the draft environmental assessment/FONSI in the staff's final environmental review document. This approach is consistent with NRC regulations.

1.8.5 The NRC Final Environmental Review Document and Findings

The NRC staff will issue the final environmental review document as part of the licensing review documentation for each site-specific licensing action (i.e., new license, renewal, amendment). The final document will provide the NRC staff's site-specific environmental review determinations that consider public input and the evaluations in the GEIS, to the extent

applicable. The final environmental document and the site-specific Safety Evaluation Report together form the basis for the NRC's decision on whether to issue a 10 CFR Part 40 source material license to the applicant for ISL uranium milling or to grant a licensee's application to renew or amend its existing NRC license.

The NRC final action to issue a license may also be subject to a formal NRC hearing. As discussed in Section 1.8.4, 10 CFR Part 2 provides NRC's requirements concerning hearings.

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2 *IN-SITU* LEACH URANIUM RECOVERY AND ALTERNATIVES

Chapter 2 provides information on uranium recovery using the *in-situ* leach (ISL) process. The first part of the chapter gives basic information on the type of uranium deposits that are amenable to ISL technology and an overview description of the parts of an ISL facility. Sections 2.2 through 2.6 describe stages of an ISL facility's lifecycle, including preconstruction, construction, operation, aquifer restoration, and decommissioning. Development and the initial licensing decision at an ISL facility are not based on comprehensive information on all aspects of the site and planned operations (NRC, 2003a). During the preconstruction (or prelicensing) period, to support its license application, the applicant provides enough information to generally locate the ore body and understand the natural systems involved. During construction and operations, more detailed geologic and hydrologic information is collected as each area of the site is developed and brought into production. Sections 2.7 through 2.10 include discussions of aspects such as occupational radiation health monitoring, waste management, transportation, and financial assurance that are common to all ISL uranium facilities and not confined to a single stage. Section 2.11 summarizes operational experience of ISL facilities regulated by the U.S. Nuclear Regulatory Commission (NRC). Sections 2.12 and 2.13 discuss the alternatives considered in this Generic Environmental Impact Statement (GEIS).

This chapter is organized by stages in the life of an ISL facility. NRC recognizes that other than the preconstruction phase, the other four phases could be performed concurrently. However, describing the ISL process in terms of these stages aids in the discussion of the ISL process and in the evaluation of potential environmental impacts from an ISL facility.

Characteristics of Uranium Deposits That Are Amenable to ISL Extraction

Certain geologic and hydrological features make a uranium deposit suitable for ISL technologies (based on Holen and Hatchell, 1986):

- **Deposit geometry.** The operator defines well field boundaries based on the geometry of the specific uranium mineralization. The deposit should generally be horizontal and have sufficient size and lateral continuity to enable economic uranium extraction.
- **Permeable host rock.** The host rock must be permeable enough to allow the mining solutions to access and interact with the uranium mineralization. Preferred flow pathways such as fractures may short circuit portions of the mineralization and reduce the recovery efficiency. The most common host units are sandstones.
- **Confining layers.** Hydrogeologic (formation) geometry must prevent uranium-bearing fluids (i.e., lixiviant) from vertically migrating. Typically, low permeability layers such as shales or clays confine the uranium-bearing sandstone both above and below. This isolates the uranium-producing horizon from overlying and underlying aquifers.
- **Saturated conditions.** For ISL extraction techniques to work, the mineralization should be located in a hydrologically saturated zone.

2.1 Overview of ISL Uranium Recovery

Only certain uranium deposits are amenable to the ISL recovery process. To understand why the ISL recovery process is an effective recovery method for certain uranium deposits, it is necessary to understand the chemical and physical characteristics of uranium ore. This section describes the geochemistry of uranium, provides a brief geologic overview of uranium ore bodies in the four GEIS regions, and generally describes ISL facilities.

2.1.1 Geochemistry of Uranium

Natural uranium occurs in minerals as each of these isotopes: U-238 (99.274 percent), U-235 (0.720 percent), and U-234 (0.0055 percent) (EPA, 2007a) and predominantly exists in one of two ionic states: U^{6+} (the uranyl oxidized ion) and U^{4+}

(the uranous reduced ion) (EPA, 1995). In the oxidized (uranyl) state, uranium is more readily dissolved and is highly mobile in the environment (e.g., in soil, surface water, and groundwater). In the uranous (U^{4+}) state, uranium solubility is very low (i.e., it does not readily dissolve in water). Common uranous minerals include uraninite (UO_2), pitchblende (a crystalline variant of uraninite), and coffinite [$U(SiO_4)(OH)_4$] (EPA, 1995; Nash, et al., 1981).

2.1.2 Physical Characteristics of Uranium Deposits

Uranium subject to recovery in the United States is primarily found in four types of deposits: stratabound, breccia pipes, vein, and phosphatic (EPA, 1995). Deposits that are generally amenable to ISL recovery in the four GEIS regions are stratabound deposits. These deposits are contained within a single layer (stratum) of sedimentary rock. It is theorized that these deposits were formed through the transport of uranium (and associated elements) by oxidizing groundwater (i.e., groundwater with chemical properties that cause the uranium ion to lose electrons) (EPA, 1995; Nash, et al., 1981). The groundwater likely flowed through uranium-containing rocks, causing the uranium to dissolve and leach from the rock. The uranium remained soluble in the groundwater until it encountered a reducing environment, (i.e., an environment with chemical properties that caused the uranium ion to gain electrons), became less soluble in water, and precipitated.

Depending upon the environmental conditions, stratabound deposits can take a variety of physical forms and are typically described as either roll-front deposits or tabular deposits. Roll-front deposits (Figure 2.1-1) are found in basins in Wyoming, southwestern South Dakota, and northwestern Nebraska. Tabular deposits (see Figure 2.1-2) are found in the Colorado Plateau, including northwestern New Mexico.

A roll-front deposit is a uranium ore-body deposited at the interface of oxidizing and reducing groundwater (EPA, 1995; Nash, et al., 1981). In basins in Wyoming, oxidized groundwater containing uranium flowed through permeable sandstone beds until reducing groundwater was reached, and the uranium precipitated out at this interface. The sandstone beds are generally confined by low- or semi-permeable units such as claystones, siltstones, mudstones, or shales. As the oxidizing and reducing environments migrated within the sandstone beds, the uranium ore deposited over a laterally extended area (EPA, 1995). These roll-front deposits have a crescent shape and may extend hundreds of meters [feet], but may be only a few meters [feet] thick. Depending on the continuity and displacement along faults of sandstone beds and confining units, roll-front deposits can be discordant, asymmetrical, and irregularly shaped and can cut across sedimentary structures.

The tabular deposits of the Colorado Plateau were formed when oxidized groundwater with higher concentrations of uranium and vanadium flowed through zones of highly permeable organic matter (humates), gases (hydrogen sulfide), or liquids capable of reducing the uranyl ion (EPA, 1995). The uranium deposited in the areas where the reducing conditions were created. The deposits are typically tabular and can be found in sandstones, limestones, siltstones, and conglomerates scattered throughout the Colorado Plateau, including northwestern New Mexico. The tabular deposits found in northwestern New Mexico result from organic matter and occur in sandstones and siltstones. Like roll-front deposits, tabular uranium deposits in Northwestern New Mexico are amenable to uranium extraction by ISL techniques. The tabular deposits are confined within low permeability layers and have sufficient size and lateral continuity to allow

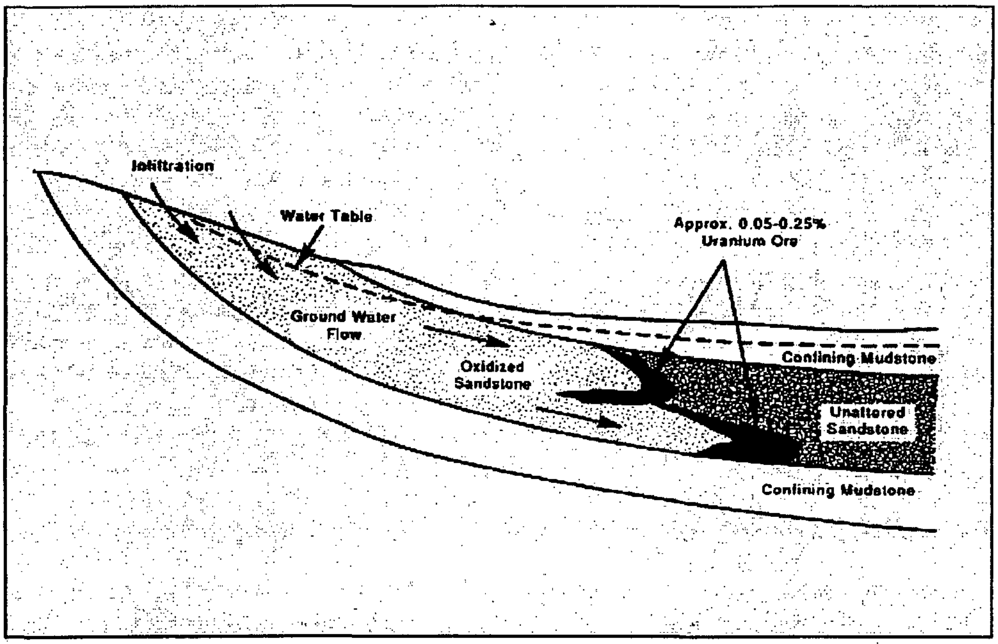

Figure 2.1-1. Simplified Cross Section of Sandstone Uranium Roll-Front Deposits Formed by Regional Groundwater Migration (NRC, 1997a)

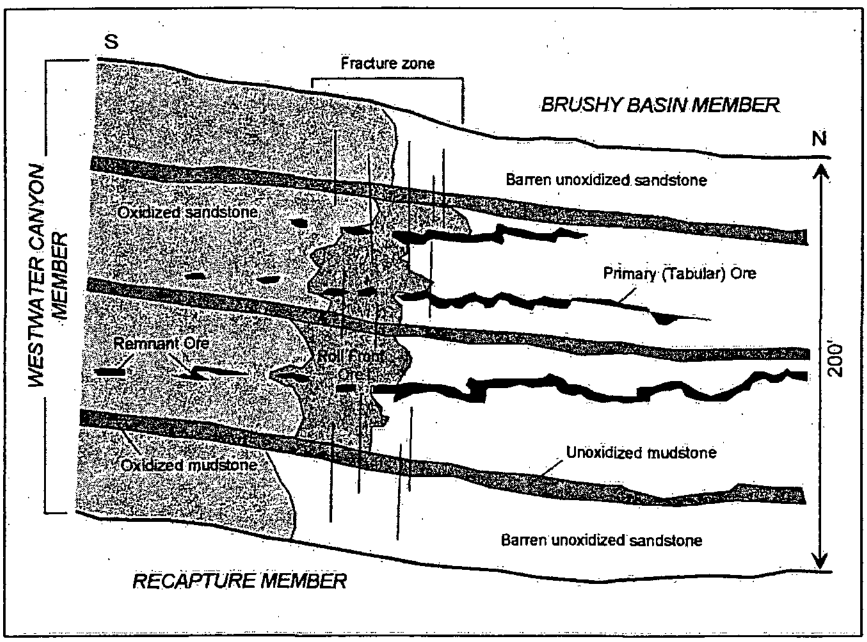

Figure 2.1-2. Schematic Diagram of the Types of Tabular Stratabound Uranium Deposits in the Grants Uranium District, New Mexico (Modified from Holen and Hatchell, 1986)

economic extraction of uranium. These deposits can range from about 0.5 to 2 m [2 to 6 ft] thick and be hundreds of meters [feet] wide. These deposits have provided over 50 percent of the uranium production in the United States (EPA, 1995).

Uranium concentrations in the ore deposit vary depending on system geochemistry and hydrology. For example, in New Mexico, uranium deposits typically contain about 0.2 to 0.3 percent U_3O_8 by weight, while deposits in Wyoming contain lower concentrations (about 0.1 to 0.25 percent) (Energy Information Administration, 2004; McLemore, 2007). The depth to the uranium mineralization ranges from about 100–300 m [328 to 984 ft] (e.g., Church Rock, New Mexico; Gas Hills, Wyoming; Smith Ranch, Wyoming; and Crow Butte, Nebraska) to greater than 560 m [1,840 ft] at Crownpoint, New Mexico. The most common uranium minerals in roll-front deposits are uraninite (UO_2), pitchblende, and coffinite [$U(SiO_4)(OH)_4$]. Minor quantities of the uranium-vanadium mineral tyuyamunite [$Ca(UO_2)_2(VO_4)_2 \cdot H_2O$] are also typically present (Nash, et al., 1981).

2.1.3 General Description of ISL Facilities

This section briefly describes the layout of an ISL facility. More detailed descriptions of the individual stages of ISL uranium recovery (construction, operations, aquifer restoration, decommissioning/reclamation) are included in Sections 2.3 through 2.6. A commercial ISL facility consists of both an underground and a surface infrastructure. The underground infrastructure includes injection and production wells drilled to the uranium mineralization zone, monitoring wells drilled to the surrounding ore body aquifer and to the adjacent overlying and underlying aquifers, and perhaps deep injection wells to dispose of liquid wastes. ISL facilities in the uranium milling regions considered in this GEIS (i.e., Wyoming West, Wyoming East, Nebraska-South Dakota-Wyoming, and Northwestern New Mexico) are commonly exposed to freezing conditions during winter months. Therefore, pipelines to transfer groundwater extracted from the well fields to the uranium processing circuit are buried to avoid freezing and thus are considered to be part of the underground infrastructure.

ISL facilities also include a surface infrastructure that supports uranium processing. The surface facilities can include a central uranium processing facility, header houses to control flow to and from the well fields, satellite facilities that house ion-exchange columns and reverse osmosis equipment for groundwater restoration, and ancillary buildings that house administrative and support personnel. Surface impoundments such as solar evaporation ponds may be constructed to manage liquid effluents from the central processing plant and the groundwater restoration circuit (Figure 2.1-3).

The surface extent of a full-scale (i.e., commercial) ISL facility includes a central processing facility and supporting surface infrastructure for one or more well fields (sometimes called mine units) and encompasses about 1,000 to 6,000 ha [2,500 to 16,000 acres] (NRC, 1992, 1997a) (see Section 2.11). However, the total amount of land

What is Yellowcake?

Yellowcake is the product of the uranium extraction (milling) process; early production methods resulted in a bright yellow compound, hence the name *yellowcake*. The material is a mixture of uranium oxides that can vary in proportion and in color from yellow to orange to dark green (blackish) depending on the temperature at which the material was dried (level of hydration and impurities). Higher drying temperatures produce a darker, less soluble material. Yellowcake is commonly referred to as U_3O_8 and is assayed as pounds U_3O_8 equivalent. This fine powder is packaged in drums and sent to a conversion plant that produces uranium hexafluoride (UF_6) as the next step in the manufacture of nuclear fuel.

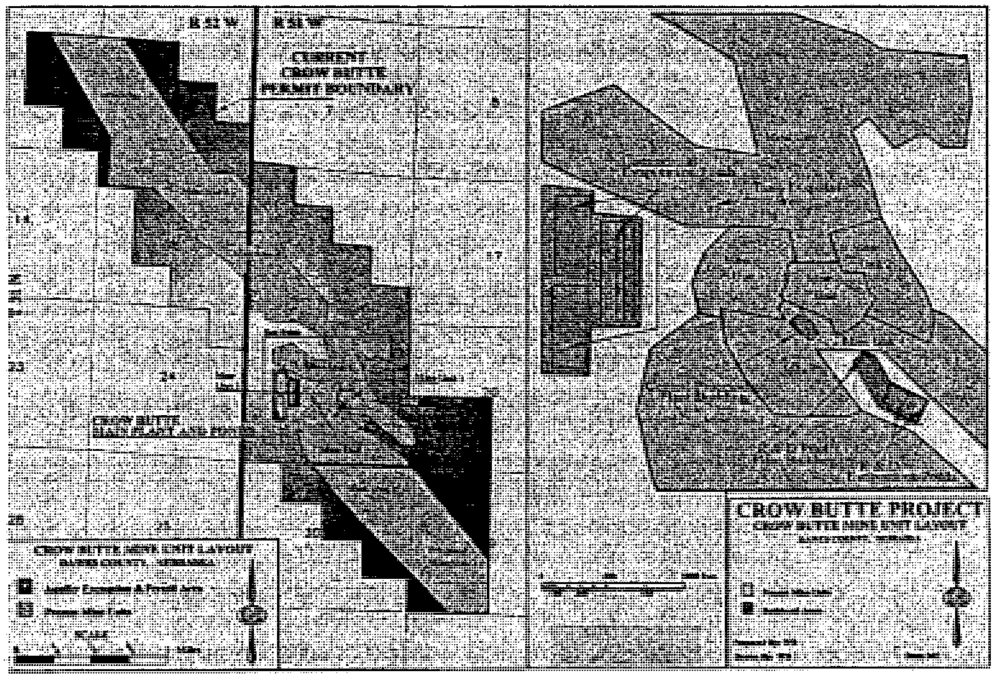

Figure 2.1-3. Layout of the Crow Butte Uranium Project in Dawes County, Nebraska (From Crow Butte Resources, Inc., 2007)

disturbed by such infrastructure and ongoing activities at any one time is much smaller, and only a small portion around surface facilities is fenced to limit access (Figures 2.1-3 and 2.1-4). Well fields typically are not enclosed by fencing.

NRC establishes the total flow rates and the maximum amount of uranium that can be produced annually at a commercial ISL facility using license conditions. NRC-licensed flow rates typically range from about 15,100 to 34,000 L/min [4,000 to 9,000 gal/min], and licensed maximum limits on annual uranium production range from about 860,000 to 2.5 million kg/yr [1.9 million to 5.5 million lb/yr] of yellowcake (NRC, 1995, 1998a,b, 2006, 2007). Actual production rates are generally somewhat lower than these limits (Energy Information Administration, 2008).

2.2 Preconstruction

The applicant must characterize the potential site to support an application for a license to construct and operate an ISL facility (NRC, 2003a, Chapters 2 and 7). During the initial licensing review for a new ISL facility, NRC does not require a comprehensive discussion of all aspects of the site and of planned operations (NRC, 2003a). Instead, at this stage, the applicant needs to provide enough information to generally locate the uranium mineralization, understand the natural systems involved, and establish baseline conditions prior to operation. If a license is granted, more site-specific data are collected during the construction and operations phases of the ISL facility. For example, the licensee would collect more detailed geologic information and perform pump tests as each well field is developed (NRC, 2003a). This site-specific data confirms that the well field possesses the characteristics that will make it suitable for ISL extraction before being brought into production.

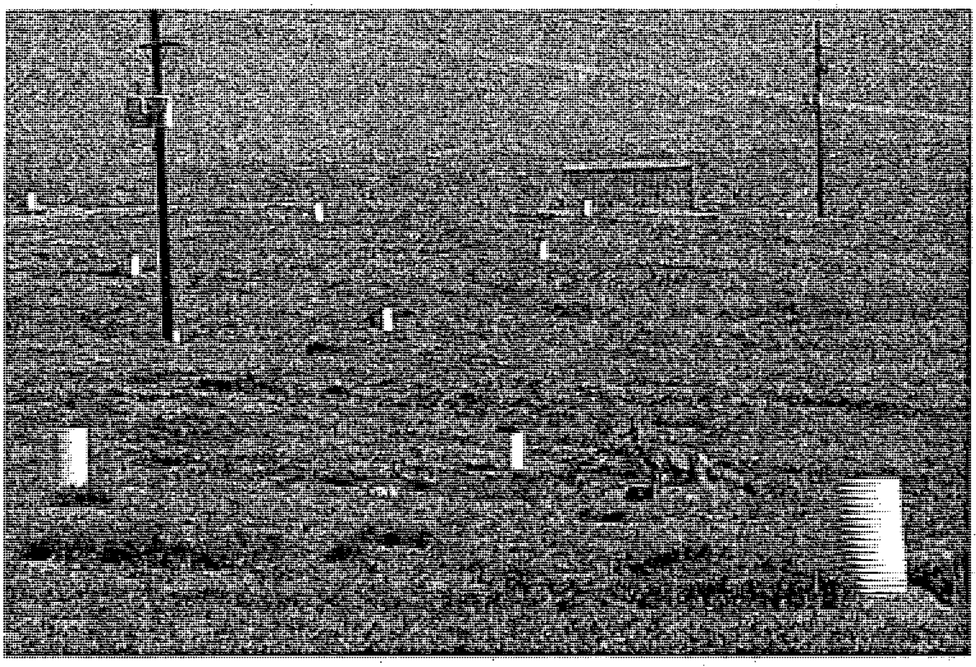

Figure 2.1-4. Well Heads and a Header House at Smith Ranch, Converse County, Wyoming

The general types of site baseline information to be provided by the license applicant are described in NRC guidance (NRC, 2003a, Chapter 2; 1982). Specific features of the site or its environs may also be identified and used by the applicant to support the proposed facility description. The applicant provides maps to locate the proposed site and identify proposed surface facilities, well fields, and other features of the ISL facility. In addition to providing information about the proposed site location and the environment in the vicinity of that location (e.g., water use, subsurface geology, hydrology, ecology, historical and cultural resources), the applicant also provides population data and assessments of trends in population and industry (NRC, 2003b, Appendix C).

Given the nature of the ISL uranium recovery process, hydrologic characterization of the site is a critical component of the preconstruction activities. This characterization describes surface-water features in the site area and the specific groundwater hydrogeologic setting, including detailed hydrogeologic and hydraulic descriptions of the proposed uranium production zone, adjacent aquifers, and low-permeability units that isolate the production zone.

In support of its license application, the applicant determines the background groundwater quality at and in the vicinity of the site (NRC, 2003a). An NRC-accepted list of constituents to be sampled for determining baseline water quality is shown in Table 2.2-1. This list includes the constituents and water quality parameters that are expected to increase in concentration as a result of ISL activities and that are of concern to the water use of the aquifer. Alternatively, applicants can propose a list of constituents that is tailored to a particular location. In such cases, sufficient technical bases must be provided for the selected constituent list (NRC, 2003a). State and other federal agencies with jurisdiction over groundwater could also specify

Table 2.2-1. Typical Baseline Water Quality Parameters and Indicators*		
Physical Indicators		
Specific Conductivity	Total Dissolved Solids†	pH‡
Major Elements and Ions		
Alkalinity	Chloride	Sodium
Bicarbonate	Magnesium	Sulfate
Calcium	Nitrate	
Carbonate	Potassium	
Trace and Minor Elements		
Arsenic	Iron	Selenium
Barium	Lead	Silver
Boron	Manganese	Uranium
Cadmium	Mercury	Vanadium
Chromium	Molybdenum	Zinc
Copper	Nickel	
Fluoride	Radium-226§	
Radiological Parameters		
Gross Alpha‖	Gross Beta	
Boron	Manganese	Uranium
Cadmium	Mercury	Vanadium
Chromium	Molybdenum	Zinc
Copper	Nickel	
Fluoride	Radium-226§	
Radiological Parameters		
Gross Alpha‖	Gross Beta	

*Based on U.S. Nuclear Regulatory Commission (NRC). NUREG–1569, "Standard Review Plan for *In-Situ* Leach Uranium Extraction License Applications—Final Report." Table 2.7.3-1. Washington, DC: NRC. June 2003.
† Laboratory only.
‡ Field and laboratory determination.
§ If site initial sampling indicates the presence of thorium-232, then radium-228 should be considered in the baseline sampling, or an alternative may be proposed.
‖ Excluding radon, radium, and uranium.

constituents, which may or may not be included in the NRC-accepted list. In this case, the applicant would be accountable to the subject state or federal agency for characterizing and restoring these constituents.

To determine background groundwater quality conditions, at least four sets of samples, spaced sufficiently in time to establish seasonal variability, should be collected and analyzed for each constituent (NRC, 2003a). NRC verifies the accuracy of the water quality data by ensuring that the applicant's or licensee's procedures include (1) acceptable sample collection methods, (2) a set of sampled parameters that is appropriate for the site and ISL extraction method, and (3) collection of sample sets that are sufficient to represent natural spatial and temporal variations in water quality.

Applicants or licensees also collect site-specific data to establish background radiological characteristics. These data should include measurements of radionuclides occurring in important flora and fauna, soil, air, and surface and groundwaters that ISL operations could affect.

2.3 Construction

General construction activities associated with ISL facilities include drilling wells, clearing and grading associated with road construction and building foundations, building construction, trenching and laying pipelines, and building evaporation pond impoundments. Construction-related activities continue throughout much of the life of the project as well fields are developed and additional wells and surface structures are added. For a satellite facility, the initial construction of the surface facilities would take about 2–3 months (NRC, 2004). Construction and testing of a well field may require about a year and a half (NRC, 2006), with four to eight drill rigs and support vehicles operating in the field (NRC, 2004, 1997a). Well field construction requires about 50 to 75 personnel (NRC, 2004).

2.3.1 Underground Infrastructure

The underground infrastructure at an ISL facility is established to inject and extract lixiviant, monitor groundwater quality, and transfer fluids between the wells and production facilities.

> **Lixiviant**
>
> A leachate solution composed of native groundwater and chemicals added by the ISL facility operator and pumped underground to mobilize (dissolving) uranium from a uranium ore body.

2.3.1.1 Well Fields

Well Field Design. The licensee establishes the injection and production well patterns to recover uranium using an approach and site characterization information that are reviewed and approved by NRC. The well patterns are developed for a specific site, and installation for a given well field is based on the subsurface geometry of the ore deposit. Various pattern shapes are used, although five-spot and seven-spot patterns are common (NRC, 2003a). A typical well arrangement using five- and seven-spot patterns is shown in Figure 2.3-1. Because roll-front uranium deposits normally have irregular shapes, some of the well patterns in a given well field are also irregular, and the licensee may alter well patterns to fit the size, shape, and boundaries of individual ore bodies. Depending on ore body geometry and surface topography, well spacing for common well patterns (e.g., the five-spot or seven-spot patterns) is typically between 12 and 50 m [40 and 150 ft] apart (NRC, 1998; Energy Metals Corporation, 2007a; Lost Creek ISR, LLC, 2007).

Ore body size and geometry will also influence the number of wells in a well field. For example, at the Crow Butte ISL facilities in Dawes County, Nebraska, the number of injection and production wells varied from about 190 in the first well field (MU-1) to about 900 in later well fields (MU-5 and MU-6) (NRC, 1998b).

Three types of wells are predominant at uranium ISL facilities:

- Injection wells for introducing solutions into the uranium mineralization
- Production wells for uranium production
- Monitoring wells for assessing ongoing operations

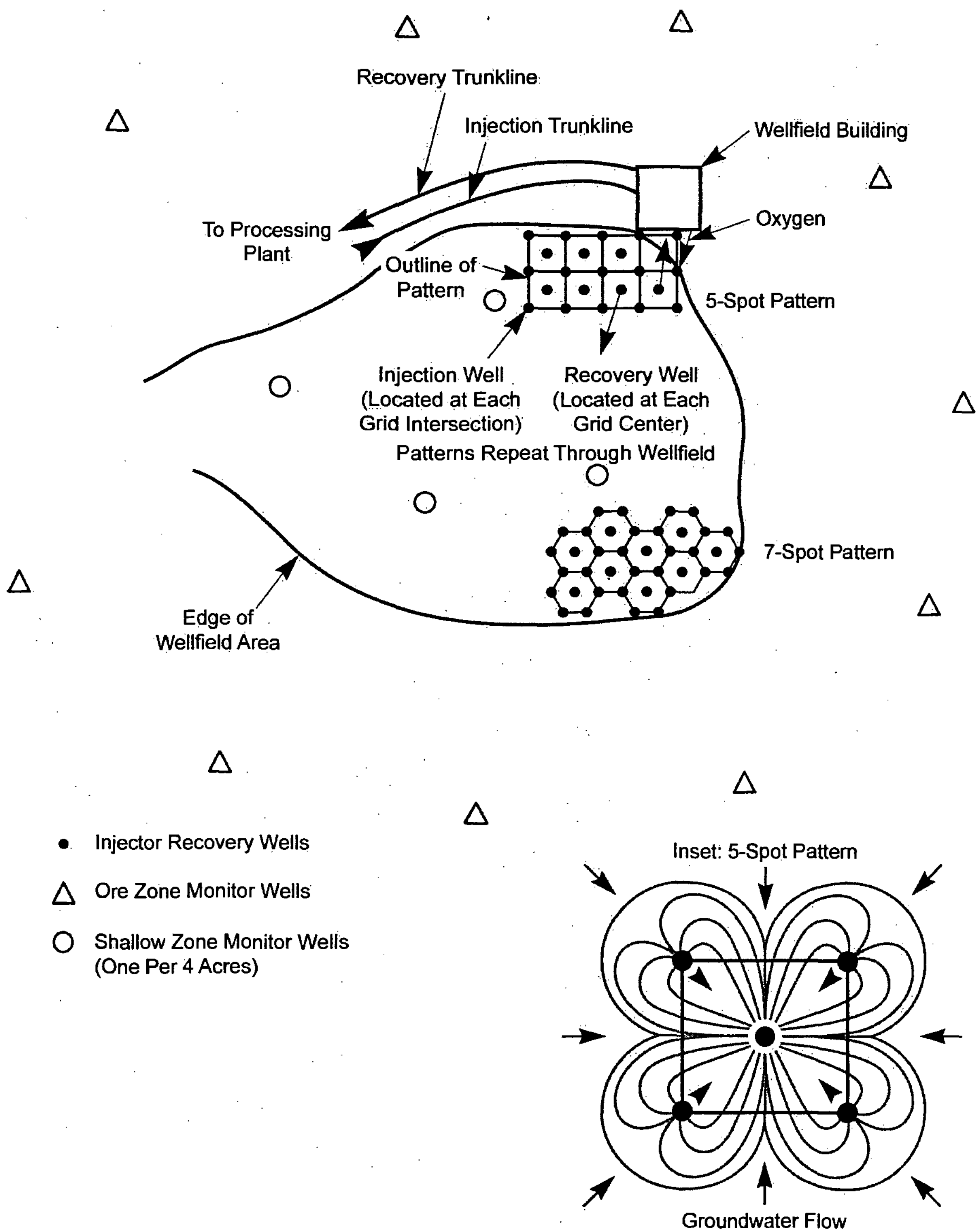

Figure 2.3-1. Schematic Diagram of a Well Field Showing Typical Injection/Production Well Patterns, Monitoring Wells, Manifold Buildings, and Pipelines (From NRC, 1997a)

The licensee or applicant may also drill deep injection wells permitted by the EPA or state and approved by NRC for liquid waste disposal. Injection and production wells are connected to manifolds in a nearby header house (Figure 2.3-2). The manifolds connect to pipelines that carry solutions to and from the recovery plant or satellite facility. Meters and control valves (usually computerized) in individual well lines monitor and control flow rates and pressures for each well to maintain water balance and to aid in identifying leaks (Figure 2.3-3). The well field piping is typically high-density polyethylene pipe, polyvinyl chloride (PVC), and/or steel. Individual well lines and larger trunk lines to the recovery plant are buried below the frost line {e.g., 2 m [6 ft] in Wyoming} to prevent solutions from freezing (NRC, 2006).

Commercial-scale uranium ISL facilities usually have more than one well field. For example, the Crow Butte facility in Dawes County, Nebraska, has constructed 10 well fields since 1991 and has plans for an eleventh (Crow Butte Resources, Inc., 2007). The Reynolds Ranch satellite facility in Converse County, Wyoming, plans to establish eight well fields (NRC, 2006). As described in Section 2.1.1, the well fields are developed in sequence, and at any one time, different well fields are likely to be in different stages of construction, operation, aquifer restoration, and decommissioning/reclamation (Crow Butte Resources, Inc., 2007). Construction and testing for each well field may require up to a year and a half before production begins (NRC, 2006). The locations and boundaries for each well field are adjusted as more detailed data on the subsurface stratigraphy and uranium mineralization distribution are collected during well field construction.

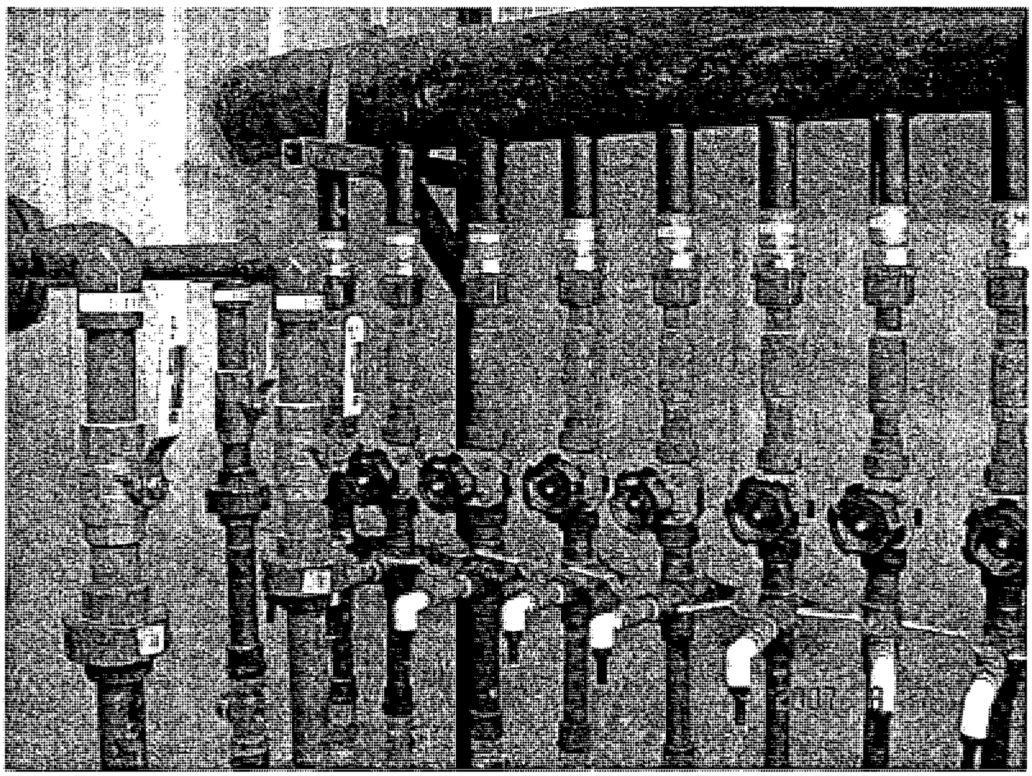

Figure 2.3-2. Manifold Inside Well Field Header House at an ISL Facility

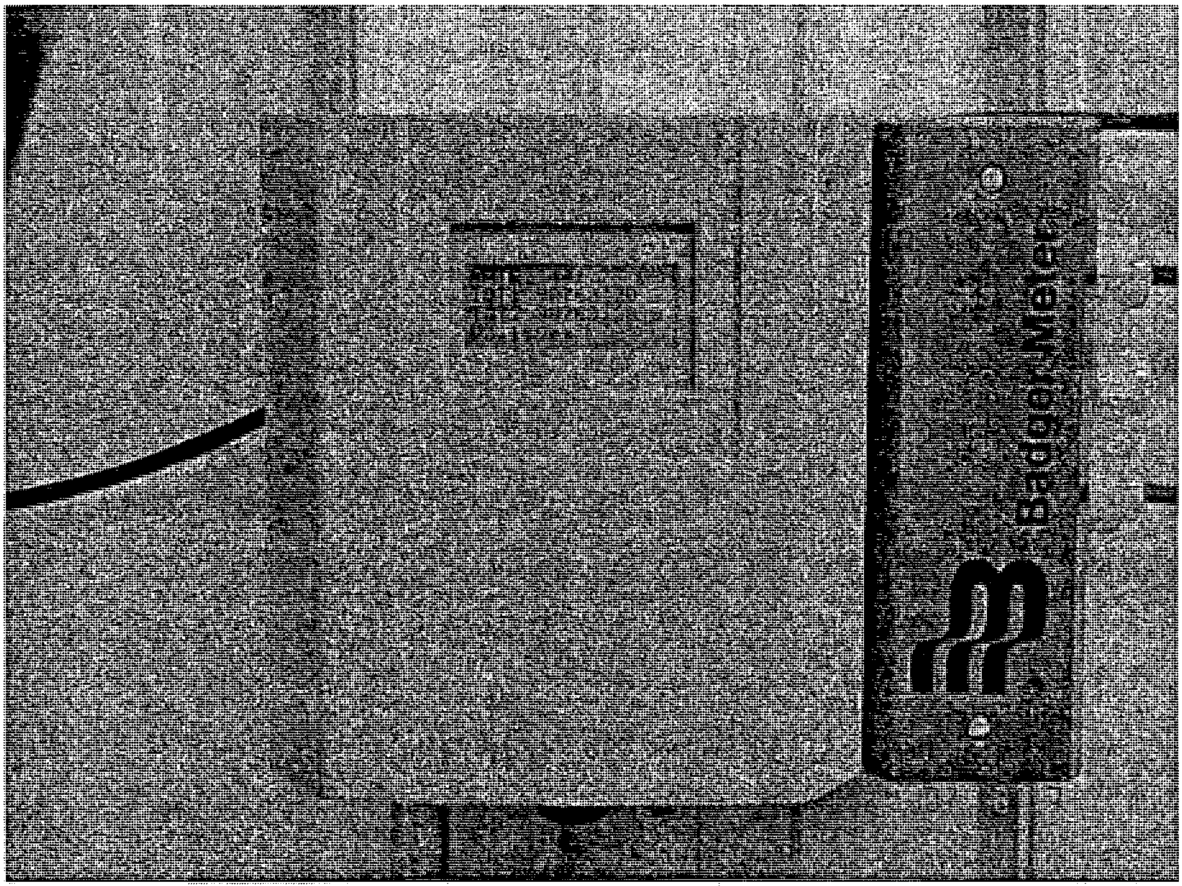

Figure 2.3-3. Computerized Meter for Monitoring Well Field Flow Rates

Well Drilling. Standard drilling techniques are used to develop ISL well fields. Temporary access roads for drilling rig trucks, support vehicles, and excavators lead to each well location. At the drilling location, a flat drill pad may be graded. At most ISL well fields, injection, production, and monitoring wells are drilled to the desired depth {e.g., 100–300 m [328–984 ft] for a target uranium production zone} by a standard method such as mud rotary drilling. In this method, a string of drill pipe and a drill bit are rotated against the formation. A water-based drilling fluid (mud) is circulated through the hole to lubricate the bit and to carry the drilled material to the surface. A temporary mud pit is excavated in the ground next to the drill site to contain the drilling mud. Depending on the depth to the uranium mineralization and site-specific hydrogeological characteristics, other drilling methods may be used.

While a well field is being drilled, detailed stratigraphic information and uranium ore occurrence data are collected. The locations and boundaries of a well field are then adapted to the subsurface geometry of a specific ore body. As the driller reaches the final depth of a well, it is usually logged with a variety of downhole geophysical tools (e.g., natural gamma ray logging, electrical resistivity) to characterize the well stratigraphy and is then reamed out to adjust the borehole diameter to construct a well. Residual cuttings and drilling fluids are typically held in the mud pit after drilling and construction activities are completed. Depending on state and local

regulations, such pits are backfilled and graded or are alternatively emptied and cleaned, and residual solids and liquids are transported and disposed of offsite (NRC, 2006).

Well Construction. The geologic units above the aquifer of interest typically are sealed with steel, fiberglass, or PVC casing grouted in place (Figure 2.3-4). This firmly sets the casing and prevents groundwater leakage from or to overlying aquifer(s). Grouts and casing materials are selected by the licensee or applicant to be inert with respect to the lixiviant and based on the depth of the well and anticipated well pressures. PVC or fiberglass casings are generally used in wells less than 300 m [1,000 ft] deep (NRC, 2003a). Wells deeper than 300 m [1,000 ft], or those subjected to high-pressure grouting techniques, are subject to collapse. In these instances, steel or fiberglass casing is generally necessary. The possibility that chemical reactions may take place between the casing and the mineral constituents in the water affects the choice of casing material used for monitoring wells. Iron oxide in steel-cased wells will adsorb trace and heavy metals dissolved in the groundwater. The applicant would use casing that is inert to these metals, such as PVC or fiberglass.

Depending on local hydrogeologic conditions, the following well construction steps generally are followed:

- Open holes to sections of the uranium mineralized aquifers screened with either steel, fiberglass, or PVC
- Screens are then connected to the ground surface with steel, fiberglass, or PVC riser pipes.
- The space between the casing and the borehole (i.e., the annulus) is filled with properly graded sand or gravel pack material, or the formation is simply left to collapse around the screen.
- A bentonite clay seal is installed above the top of the screen.
- The annulus above the bentonite seal between the screen/riser pipe assembly and the borehole is typically grouted to the ground surface with a mixture of cement, bentonite, and water.

Well heads are completed above ground to make access and maintenance easier. Depending on local weather and land conditions, a variety of protective enclosures is used around the well head to protect it from the elements. Before the well head construction of an injection or production well is completed, the well is connected by underground piping to an injection or production manifold in a nearby header house.

<u>Mechanical Integrity Testing</u>

After completion and before bringing into service, injection and recovery wells are tested for mechanical integrity. As described in NRC (2003a, Section 3.1.3), a packer is set above the well screen, and the well casing is filled with water. At the surface, the well is pressurized with either air or water to 125 percent of the maximum operating pressure, which is calculated based on the strength of the casing material and depth. The well pressure is monitored to ensure significant pressure drops do not occur through borehole leaks. A pressure drop of no more than 10 percent in a period of 10 to 20 minutes indicates the casing and grout are sound (i.e., do not leak) and the well is fit for service. Well integrity tests are also performed if a well has been damaged by surface or subsurface activities or has been serviced with equipment or procedures that could damage the well casing, such as insertion of a drill bit or cutting tool. Additionally, each well is retested periodically (once each 5 years or less) to ensure its continued integrity. If a well casing fails a mechanical integrity test, the well is taken out of service, repaired, and retested. If an acceptable test cannot be obtained after repairs, the well is plugged and abandoned.

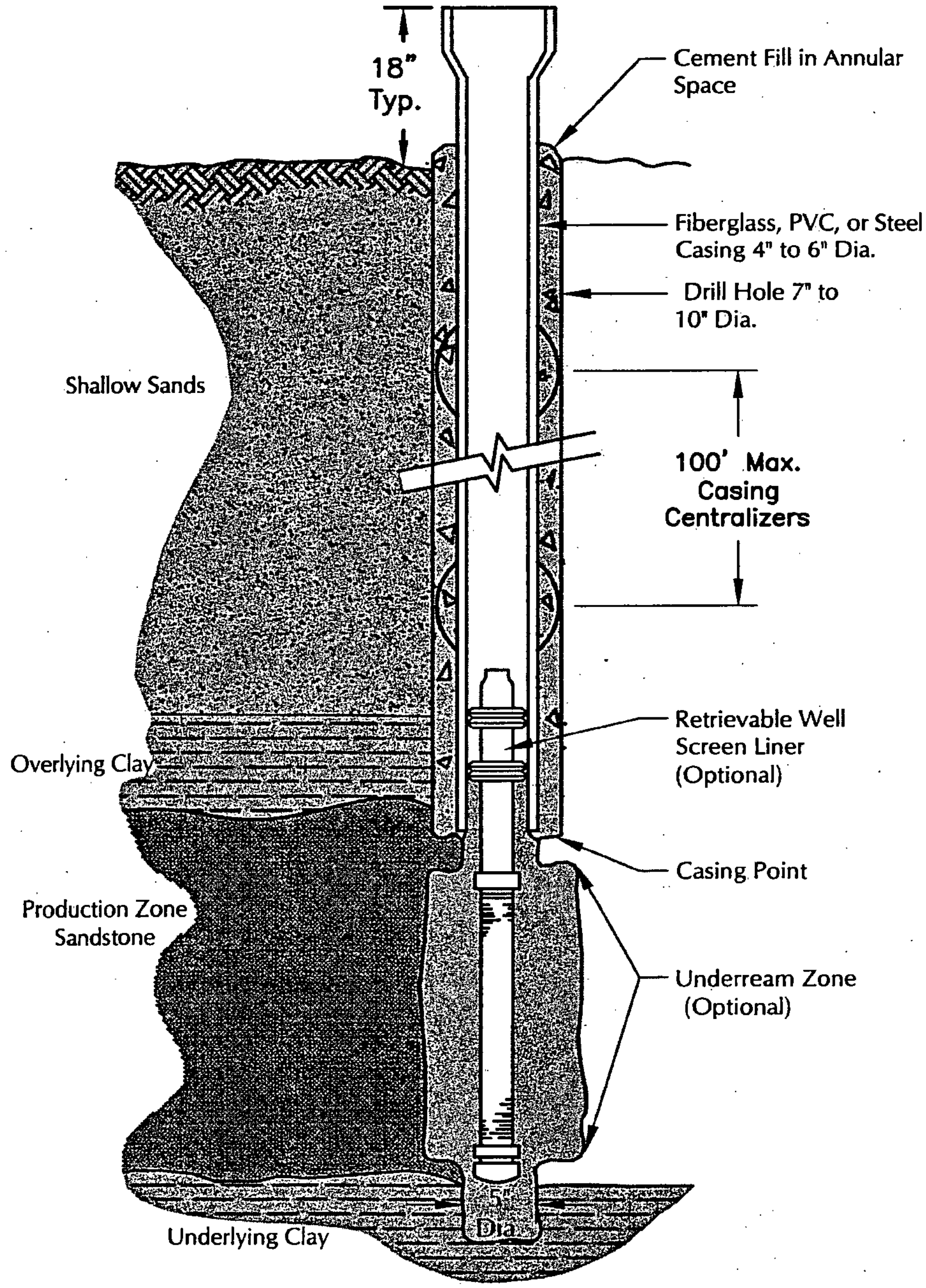

Figure 2.3-4. Cross Section of a Typical Injection, Production, or Monitoring Well Completed Using the Underreamed Method (Modified From NRC, 1997) [1 in = 2.54 cm; 1 ft = 0.305 m]

Monitoring wells are not usually connected to any other structure but can have cables connected to sensors in the well (NRC, 2006).

Well Development and Integrity Testing. Wells are usually developed using an air lift method or other pumping method appropriate for local conditions. Well development removes remaining drilling mud, cuttings, and fine particles (i.e., silt and clay) from inside the well, the screen, and the surrounding gravel/sand pack. Development improves well yield by enhancing hydraulic communication between the undisturbed aquifer and the well. The licensee also performs a mechanical integrity test (MIT) to verify that the well casing does not fail, causing water loss during injection or recovery operations. In an MIT, the bottom and top of the casing are plugged (sealed) with an inflated downhole packer or similar sealing device. The well is pressurized, and pressure gauges monitor pressure changes inside the casing. Based on site-specific conditions, after maintaining a specified pressure for a specified period without a measurable decrease, the well casing is considered to have passed an MIT and the well is fit for injection or production operations (NRC, 2006).

2.3.1.2 Pipelines

A network of process pipelines and cables are typically installed as part of the underground infrastructure:

- Between the central uranium processing facility or the satellite facility and the header houses for transporting lixiviant
- Between the header houses and well fields for injecting and recovering lixiviant
- Between the central processing facility and wastewater disposal sites (e.g., deep injection wells, evaporation ponds)

The network of process pipelines and cables required in ISL operations may be buried because of freezing temperatures that are common in the regions considered in this GEIS and because of safety and land imprint issues. Depending on local winter conditions, burial trenches can be excavated as deep as 2 m [6 ft] to avoid freezing (e.g., NRC, 2006). Pipes used to convey water, lixiviant, and wastewater are placed in these unlined trenches along with numerous electrical, communication, and sensor cables. Trenches are typically backfilled with native soil and graded to surrounding topography. Pipeline pressures are measured and recorded to monitor for potential leaks and spills that might result from the failure of fittings and valves.

2.3.2 Surface Facilities

ISL facilities require construction of surface facilities, ranging from standard industrial buildings with associated power, water, heating, ventilation, and air conditioning equipment to specialized structures such as evaporation ponds (NRC, 2003a). Examples of surface facilities include

- Central uranium processing facilities, with a typical footprint of about 3,060 m^2 [33,000 ft^2] (NRC, 1998b)
- Satellite facilities {about 1,200 m^2 [13,000 ft^2] (NRC, 2006)} that contain remote ion-exchange facilities

- Administration, operation, and field offices or other support facilities
- Pump and header houses for equipment to transfer lixiviant between the wells and pipelines
- Liquid effluent handling facilities, such as solar evaporation ponds. Typical evaporation ponds have surface areas ranging from 0.04 to 2.5 ha [0.1 to 6.2 acres] (NRC, 1998a; Crow Butte Resources, Inc., 2007)

Between the well fields and surface facilities, roads may be constructed (dirt and/or paved) for access:

- To well fields and pump houses
- Between the well fields/pump houses and the satellite facilities
- Between the satellite facilities and the central processing facility
- Between the processing plant and transportation routes

The surface facilities and access roads are designed and built using standard construction techniques. Specific building codes are used as appropriate. Construction vehicles may include bulldozers, drilling rigs, water trucks, forklifts, pump hoist trucks, coil tubing trucks, pickup trucks, portable air compressors, and other support vehicles.

Evaporation ponds may be constructed to dispose of effluent from the processing circuit or from aquifer restoration activities. These impoundments are designed and constructed with liners and leak detection systems installed in accordance with applicable NRC guidance (NRC, 2008a). Embankments for these evaporation ponds are constructed to resist erosion from wave action. The size and shape of the ponds are designed based on the amount of water that must be managed and the evaporation rates for the region. Sufficient space is provided so that the contents of one pond may be transferred to another to allow any identified pond system leaks to be repaired while meeting freeboard requirements from possible wave action.

2.4 Operations

Although specific operations will vary depending on the individual operator and site-specific characteristics, the ISL uranium recovery process generally involves two primary operations: (1) injection of barren lixiviant to mobilize uranium in underground aquifers and (2) extracting and processing the pregnant lixiviant in surface facilities to recover the uranium and prepare it for shipment (see text box).

Basic Steps in Uranium Mobilization

- **Groundwater Injection.** The operator injects a nonuranium-bearing (barren) extraction solution or lixiviant through wells into the mineralized zone. The lixiviant moves through pores in the production zone, dissolving uranium and other metals.
- **Groundwater Extraction.** Production wells withdraw the resulting "pregnant" lixiviant, which now contains uranium and other dissolved metals, and pump it to a central processing plant or to a satellite processing facility for further uranium recovery and purification.

2.4.1 Uranium Mobilization

During ISL operations, chemicals, such as sodium carbonate/bicarbonate, ammonia, sulfuric acid, gaseous oxygen, and hydrogen peroxide, are added to the groundwater to produce a leaching solution or lixiviant. The lixiviant is injected into the production zone to mobilize (dissolve) uranium from the underground formation and subsequently remove uranium from the deposit.

2.4.1.1 Lixiviant Chemistry

The lixiviant that is selected must leach uranium from the host rock and keep it in solution during groundwater pumping from the host aquifer. Based on experience with conventional uranium milling, early ISL facilities tended to use aggressive acid-based lixiviants, such as sulfuric acid (International Atomic Energy Agency, 2001). These acid-based systems generally achieved high yield and efficient, rapid uranium recovery, but they also dissolved other heavy metals associated with uranium in the host rock and other chemical constituents that required additional remediation. In the United States, acid-based lixiviants have been used only for small-scale research and development operations [e.g., Nine Mile Lake and Reno Ranch in Wyoming (Mudd, 2001)], but have not been used in commercial operations (Davis and Curtis, 2007; International Atomic Energy Agency, 2005). Licensees or applicants may propose the use of acid-based lixiviants in the future. Other technologies that used ammonia-based lixiviants experienced difficulties: the ammonia tended to adsorb onto clay minerals in the subsurface. The ammonia desorbs slowly from the clay during restoration, and therefore the system requires that much larger amounts of groundwater be removed and processed during aquifer restoration (Energy Information Administration, 1995; Davis and Curtis, 2007). Although applicants or licensees may decide to use different lixiviants for a given deposit (see text box "Lixiviant Selection" in Section 2.4.1.2), ISL operations in the United States are expected to use alkaline lixiviants that are based on sodium carbonate-bicarbonate as the complexing agent and gaseous oxygen or hydrogen peroxide as the oxidizing agents (Table 2.4-1). All currently active and proposed ISL facilities in Wyoming, Nebraska, and New Mexico use alkaline-based lixiviants (NRC, 2006, 2004, 1998a, 1997a; Energy Metals Corporation, U.S., 2007a). Therefore, for the purposes of the analyses presented in this GEIS, it is assumed that alkaline lixiviants will be used in ISL uranium recovery operations.

Table 2.4-1. Typical Lixiviant Chemistry (From NRC*, 1998b)

Species	Range (in mg/L)†	
	Low	High
Sodium (Na)	≤400	6,000
Calcium (Ca)	≤20	500
Magnesium (Mg)	≤3	100
Potassium (K)	≤15	300
Carbonate (CO_3)	≤0.5	2,500
Bicarbonate (HCO_3)	≤400	5,000
Chloride (Cl)	≤200	5,000
Sulfate (SO_4)	≤400	5,000
Uranium (as U_3O_8)	≤0.01	500
Vanadium (as V_2O_5)	≤0.01	100
Total Dissolved Solids	≤1,650	12,000
pH (in std unit)	≤6.5	10.5

*NRC = U.S. Nuclear Regulatory Commission
†1 mg/L is approximately equal to 1 part per million (ppm)

The principal geochemical reactions caused by the lixiviant are the oxidation and subsequent dissolution of uranium and other metals from the ore body (Davis and Curtis, 2007). These reactions are effectively the reverse of those that initially caused the uranium deposition. The oxidant (oxygen or hydrogen peroxide) in the lixiviant oxidizes uranium from the relatively insoluble tetravalent state (U^{4+}) to the more soluble hexavalent state (U^{6+}). Once the uranium is in the 6+ oxidation state, the dissolved carbonate/bicarbonate causes the formation of aqueous uranyl-carbonate complexes that maintain oxidized uranium in solution as uranyl ion (UO_2^{2+}).

2.4.1.2 Lixiviant Injection and Production

Dissolved carbonate/bicarbonate lixiviants are created by introducing reagents such as sodium carbonate/bicarbonate or by injecting carbon dioxide gas (CO_2) into the groundwater. Carbon dioxide can also be added for pH control (Table 2.4-1). Lixiviant is pumped down injection wells to the mineralized zones, where it oxidizes and dissolves uranium from the sandstone formation (Figure 2.4-1). The uranium-bearing solution migrates through the pore spaces in the sandstone and is recovered by production wells. This uranium-rich (pregnant) lixiviant is pumped to the processing plant or satellite ion-exchange facility, where the uranium is extracted through a series of chemical processes. Stripped of its uranium, the now-barren lixiviant is recharged with carbonate/bicarbonate and oxidant, and the solution is returned through the injection wells to dissolve additional uranium. This process continues until the operator determines that further uranium recovery is uneconomical.

Lixiviant Selection

The geology and groundwater chemistry determine the proper leaching techniques and chemical reagents ISL milling uses for uranium recovery. For example, if the ore-bearing aquifer is rich in calcium (e.g., limestone or gypsum), alkaline (carbonate) leaching might be used [e.g., as discussed by Hunkin (1977)], acid systems were generally considered unsuitable for Texas deposits because of higher carbonate]. Otherwise, acid (sulfate) leaching might be preferable. The leaching agent chosen for the ISL operation may affect the type of potential contamination and vulnerability of aquifers during and after ISL operations.

For example, acid leaching ISL uranium recovery at Nine Mile Lake and Reno Ranch, Wyoming, presented two major problems: (1) gypsum precipitated on well screens and within the aquifer during uranium recovery, plugging wells and reducing the formation permeability (critical for economic operation) and (2) the precipitated gypsum gradually dissolved after restoration, increasing salinity and sulfate levels in groundwater (Mudd, 2001).

Typical ISL uranium recovery operations in the United States use an alkaline sodium bicarbonate system to remove the uranium from ore-bearing aquifers. Alkaline lixiviants are used in all currently active and proposed ISL facilities in Wyoming, Nebraska, and New Mexico (NRC, 2006, 2004, 1998a, 1997a; Energy Metals Corporation, U.S., 2007) (see Table 2.4-1). Alkaline-based ISL operations are considered to be easier to restore than acid mine sites (Tweeton and Peterson, 1981; Mudd, 1998).

During the uranium recovery process, the groundwater in the production zone becomes progressively enriched in uranium and other metals that are typically associated with uranium in nature. The most common metals are arsenic, selenium, vanadium, iron, manganese, and radium. These and other constituents such as chloride, which is introduced by the ion-exchange resin system, are removed or precipitated from the groundwater during aquifer restoration after uranium recovery is completed. Aquifer restoration is detailed in Section 2.5.

The production wells are normally positioned to pump pregnant lixiviant from a number of injection wells. After processing for the uranium but before reinjection below ground, about 1–3 percent of the lixiviant, called the production bleed, is removed from the circuit and disposed (see Section 2.7.2). The purpose of the production bleed is to ensure that more groundwater is extracted than re-injected. Maintaining this negative water balance helps to ensure that there is a net inflow of groundwater into the well field to minimize the potential movement of lixiviant and its associated contaminants out of the well field.

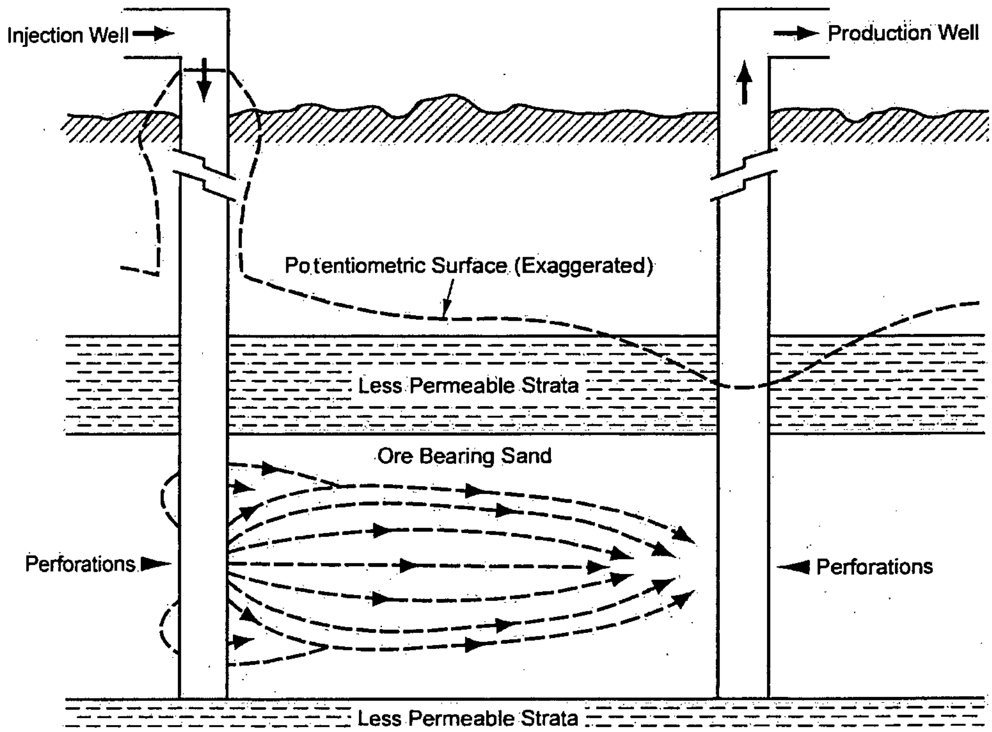

Figure 2.4-1. Idealized Schematic Cross Section To Illustrate Ore-Zone Geology and Lixiviant Migration From an Injection Well to a Production Well (From NRC, 1997a)

Pregnant lixiviant is pumped from the well fields by submersible pumps located in each production well. In some cases, booster pumps are installed in the lines to the processing plants or satellite facilities. Given the seasonal temperature variation in the four regions considered in this GEIS, the main injection and production lines to and from the processing plants may be buried up to several meters [feet] to prevent freezing. These lines are usually 10.2- to 35.6-cm [4- to 14-in]-diameter high-density polyethylene or PVC pipes. The pregnant lixiviant is enriched in uranium relative to groundwater {typically about 60 mg/L [0.0005 lb/gal]} and is also likely to contain the trace elements and contaminants as discussed previously. The pipeline pressures are monitored continuously for spills and leaks.

2.4.1.3 Excursions

ISL operations may affect the groundwater quality near the well fields when lixiviant moves from the production zone and beyond the boundaries of the well field. This unintended spread, either horizontally or vertically, of recovery solutions beyond the production zone is known as an excursion. An excursion can be caused by

- Improper water balance between injection and recovery rates
- Undetected high permeability strata or geologic faults
- Improperly abandoned exploration drill holes

- Discontinuity within the confining layers
- Poor well integrity, such as a cracked well casing or leaking joints between casing sections
- Hydrofracturing of the ore zone or surrounding units

NRC license and underground injection control (UIC) permit conditions require that licensees conduct periodic tests to protect against excursions. These include but are not limited to

- Conducting pump tests for each well field prior to operations within the well field to evaluate the confinement of the production horizon
- Continued well field characterization to identify geologic features (e.g., thinning confining layers, fractures, high flow zones) that might result in excursions
- Mechanical integrity testing of each well to check for leaks or cracks in the casing

An excursion that moves laterally from the production zone is a horizontal excursion. Vertical excursions occur where barren or pregnant lixiviant migrates into other aquifers above or below the production zone.

2.4.1.4 Excursion Monitoring

Licensees must maintain groundwater monitoring programs (see Chapter 8) to detect both vertical and horizontal excursions and must have operating procedures to analyze an excursion and determine how to remediate it. Monitoring wells are sampled at least every 2 weeks during well field operations to verify that ISL solutions are contained within the operating well field (NRC, 2003a). Geochemical excursion indicators are identified based on well field preoperational baseline water quality (see text box "Identifying Excursion Indicators and UCLs").

Identifying Excursion Indicators and UCLs

The applicant or licensee proposes excursion indicators and upper control limits (UCLs) based on lixiviant content and baseline groundwater quality (see Section 2.2.7). The licensee's safety evaluation and review panel (SERP) approve the excursion indicators and proposed UCLs. The SERP-approved UCLs are subject to the NRC staff review and oversight. UCLs are set on a well field basis and are concentrations for excursion indicators that provide early warning if leaching solutions are moving away from the well fields. As described in NRC (2003a, Section 5.7.8.3), the best excursion indicators are easily measurable parameters that are found in higher concentrations during ISL operations than in the natural waters. For example, at most ISL uranium recovery operations, chloride is selected because it does not interact strongly with minerals in the subsurface, it is easily measured, and chloride concentrations are significantly increased during ISL operations. Conductivity, which is correlated to total dissolved solids, is also considered a good excursion indicator because of the high concentrations of dissolved constituents in the lixiviant as compared to the surrounding aquifers (Staub, et al., 1986; Deutsch, et al., 1985). Total alkalinity (carbonate plus bicarbonate plus hydroxide) is used as an indicator in well fields where sodium bicarbonate or carbon dioxide is used in the lixiviant.

A minimum of three excursion indicators is selected, and the UCLs are determined using statistical analyses of the preoperational baseline water quality in the well field. The NRC staff has identified several statistical methods that can be used to establish UCLs. For example, in areas with good water quality (total dissolved solids less than 500 mg/L), the UCL may be set at a value of 5 standard deviations above the mean of the measured concentrations. Conversely, if the chemistry or a particular excursion indicator is very consistent, a concentration may be specified as the UCL. If baseline data indicate that the groundwater is homogeneous across the well field, the same UCLs may be used for all monitoring wells. Alternatively, if the water chemistry in the well field is highly variable, UCLs may be set for individual wells. An excursion is defined to occur when two or more excursion indicators in a monitoring well exceed their UCLs (NRC, 2003a). Alternate excursion detection procedures (e.g., one excursion indicator exceeded in a monitor well by a specified percentage) may also be used if approved by NRC.

The spacing of horizontal excursion monitoring wells is based on site-specific conditions, but typically they are spaced about 90–150 m [300–500 ft] apart and screened in the production zone (NRC, 2003a, 1997a; Mackin, et al., 2001a; Energy Information Administration, 1995). The distance between monitoring wells and the distance of monitoring wells from the well field are typically similar (NRC, 2006, 1997a). The specific location and spacing of the monitoring wells is established on a site-by-site basis by license condition. It is often modified according to site-specific hydrogeologic characteristics, such as the extent of the confining layer, hydraulic gradient, and aquifer transmissivity. Well placement may also be modified as the licensee gains experience detecting, recovering, and remediating these excursions.

NRC licenses also include requirements to establish monitoring wells in overlying and, as appropriate, in underlying aquifers to detect vertical excursions. Although uranium deposits are typically located in hydrogeologic units bounded above and below by adequately confining units, the possibility of vertical contaminant transport must be considered. Historically, these monitoring wells are more widely spaced than those within the host aquifer, although underlying aquifer monitoring wells may not be required under some circumstances (Mackin, et al., 2001a).

Historically, frequency of vertical monitoring wells at licensed ISL facilities has been (1) one monitoring well per 1.6 ha [4 acres] of well field in the first overlying aquifer, (2) one monitoring well per 3.2 ha [8 acres] in each higher aquifer, and (3) one monitoring well per 1.6 to 3.2 ha [4 to 8 acres] in the underlying aquifer (Mackin, et al., 2001a). These monitoring wells are typically sampled every 2 weeks during operations.

An excursion is defined to occur when two or more excursion indicators in a monitoring well exceed their UCLs (NRC, 2003a). Alternatively, since the advent of performance-based licensing, procedures to identify excursions can be imposed through site-specific license conditions. For example, an excursion may be defined to occur when one excursion indicator is exceeded in a monitoring well by a certain percentage. If an excursion is detected, the licensee takes several steps to notify NRC and confirm the excursion through additional and more frequent sampling (NRC, 2003a) (see Chapter 8). As described in NRC guidance (NRC, 2003a, Section 5.7.8.3), licensees typically retrieve horizontal excursions by adjusting the flow rates of the nearby injection and production wells to increase process bleed in the area of the excursion. To address vertical excursions, licensees may adjust injection and production flow rates in the area of the excursion and pump directly from the affected monitoring wells or from other wells drilled for that purpose. Vertical excursions are more difficult to retrieve, persisting for years in some cases (see Section 2.11.4). If an excursion cannot be recovered, the licensee may be required to stop injection of lixiviant into a well field (NRC, 2003a, Section 5.7.8.3).

2.4.2 Uranium Processing

Uranium is recovered from the pregnant lixiviant and processed into yellowcake in a multistep process (Figure 2.4-2). The following sections briefly describe key aspects of the uranium process circuit.

2.4.2.1 Ion Exchange

As pregnant lixiviant from the production wells enters the ion-exchange circuit, it may either be stored in a surge tank or sent directly to the ion-exchange columns (Figure 2.4-3). The ion-exchange columns contain ion-exchange resin composed of small, negatively charged

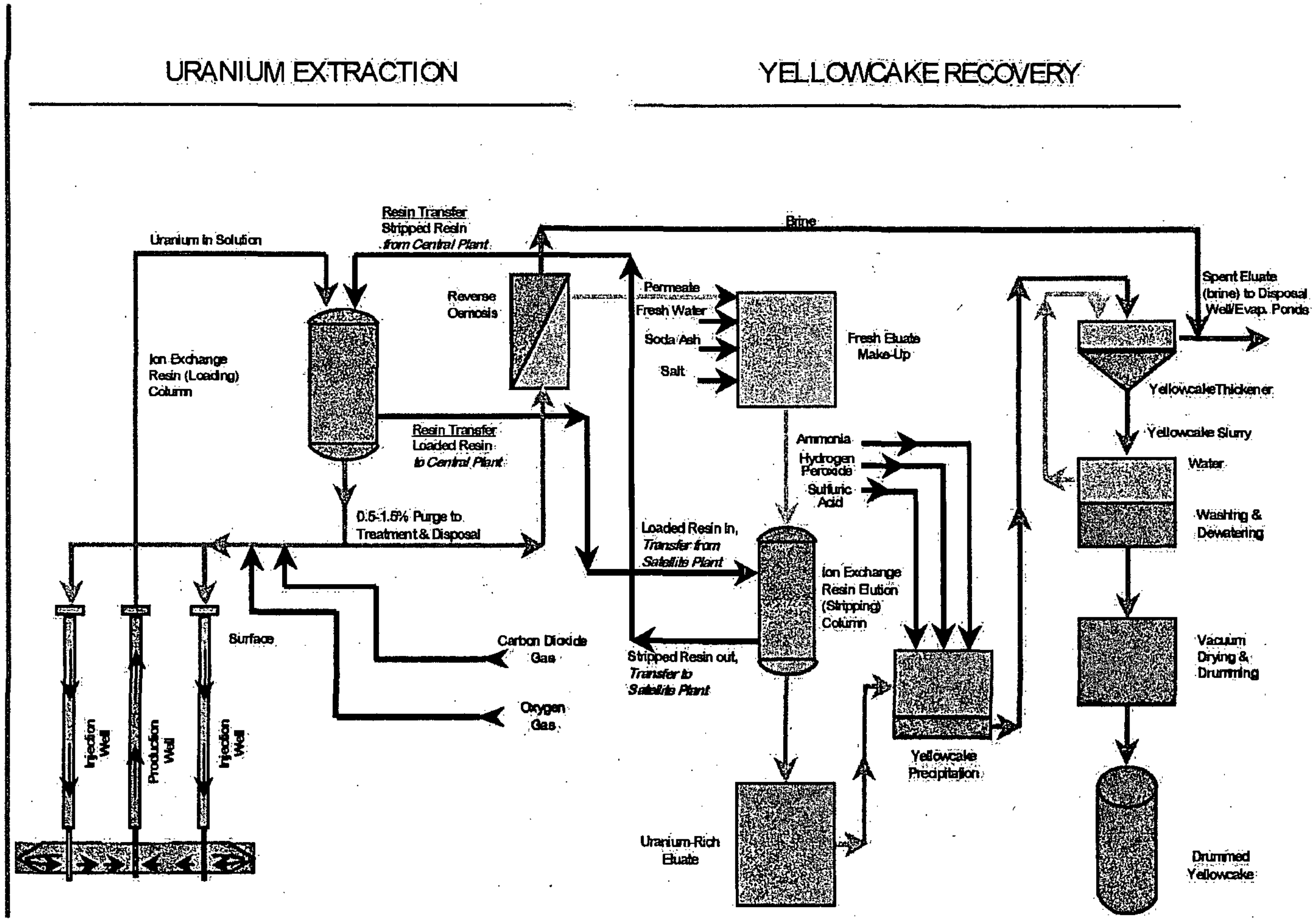

Figure 2.4-2. Flow Diagram of an ISL Uranium Recovery Process (Mackin, et al., 2001a)

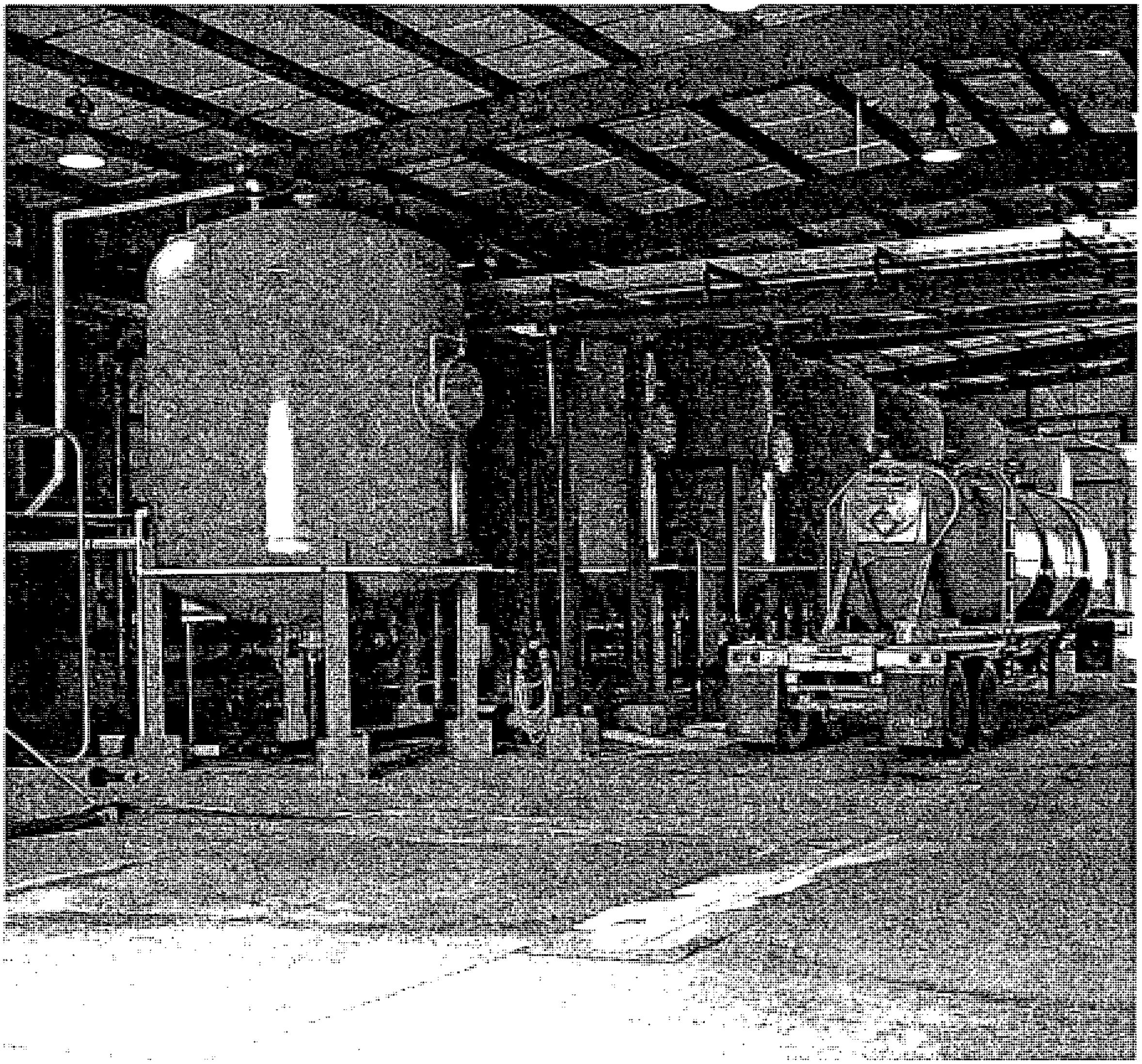

Figure 2.4-3. Typical Ion-Exchange Vessels in an ISL Facility

polymer or plastic particles. The number and size of ion-exchange columns in the circuit may vary, depending on facility design. For example, at the Smith Ranch Uranium Project in Converse County, Wyoming, the ion-exchange circuit consists of six pressurized downflow vessels, each with a volume of 14.2 m^3 [501.5 ft^3] (Stout and Stover, 1997). At the Crow Butte facility in Dawes County, Nebraska, the ion-exchange circuit consists of eight upflow columns, with a recent addition of six downflow columns, each about 3.5 m [11.5 ft] in diameter and 4.6 m [15 ft] tall and a volume of about 44 m^3 [1,554 ft^3] (NRC, 2007; Crow Butte Resources, Inc., 2007). In the ion-exchange columns, the uranium is adsorbed onto resin beads that selectively remove uranium from solution. The primary reaction is the exchange of the uranium carbonate complexes for chloride. The lixiviant exiting the ion-exchange columns normally contains less than 5 mgL of uranium (Energy Metals Corporation, U.S., 2007a; Lost Creek ISR, LLC, 2007).

Based on average uranium concentrations in production fluids at ISL sites (e.g., 120 to 150 mg/L [120 to 150 ppm]; Lost Creek ISR, LLC, 2007), greater than 95 percent of the uranium is extracted during the ion-exchange process. The (now barren) lixiviant is recharged with oxidant and bicarbonate, and is returned to the well field for reinjection and further uranium recovery. This barren lixiviant carries chloride that was exchanged for uranium on the resin. The chloride content of the water in the ore-bearing aquifer builds up with time as the lixiviant is circulated and the resin is recharged. The production bleed discussed in Section 2.4.1 is removed downstream of the ion-exchange columns, before re-injecting the barren lixiviant into the well field (see Figure 2.4-2).

When the resin beads in the ion-exchange columns become saturated with uranium, the columns are taken offline, and other columns are brought online. Some facilities may not process the ion-exchange resins further (NRC, 2004, 2006). In these facilities (called satellite facilities), the resin is discharged to a truck and then transported to a facility that has the capacity for further processing of the uranium-loaded resin. Later sections of this GEIS assess the hazards associated with transferring and transporting loaded ion-exchange resin.

2.4.2.2 Elution

At ISL facilities that can process resin, after the resin is loaded with uranium, it enters the elution circuit. In addition, uranium-loaded resins transported from satellite plants in a remote ion-exchange operation enter the processing circuit at this point. In the elution circuit, the uranium is washed (eluted) from the resin, and the resin is made available for further cycles of uranium absorption. The resin may be eluted directly in the ion-exchange column, or it may be transferred to a separate elution tank. In the elution process, the uranium is removed from the resin by flushing with a concentrated brine solution (eluant). After the uranium has been stripped from the resin, the resin may be rinsed with a sodium carbonate or bicarbonate solution. This rinse removes the high chloride eluant physically entrained in the resin and partially converts the resin to bicarbonate form. The resulting uranium-rich solution is termed pregnant or rich eluant and typically contains 8 to 20 g/L [0.067 to 0.17 lb/gal] of uranium (Mackin, et al., 2001a). It is normally discharged to a holding tank. After enough pregnant eluant is obtained, it is moved to the precipitation, drying, and packaging circuit (Mackin, et al., 2001a).

2.4.2.3 Precipitation, Drying, and Packaging

In the precipitation and drying circuit, the pregnant eluant is typically acidified using hydrochloric or sulfuric acid to destroy the uranyl carbonate complex. Hydrogen peroxide (H_2O_2) is then added to precipitate the uranium as uranyl peroxide. Caustic soda (NaOH) or ammonia (NH_3) is also normally added at this stage to neutralize the acid remaining in the eluate. The (now barren) eluant is typically recycled. Water left over from these processes may be reused in the eluant circuit or may be disposed as 11e.(2) byproduct material. Effluent management is discussed in Section 2.7.2.

> **Byproduct Material**
>
> 11e.(2) byproduct materials are tailings or waste generated by extraction or concentration of uranium or thorium processed ores, as defined under Section 11e.(2) of the Atomic Energy Act.

After the precipitation process, the resulting slurry is sent to a thickener where it is settled, washed, filtered, and dewatered (Figure 2.4-4). At this point, the slurry is 30 to 50 percent solids. This thickened slurry may be transported offsite to a uranium processing plant to produce yellowcake, or it may be filter pressed to remove additional water, dried, and packaged onsite.

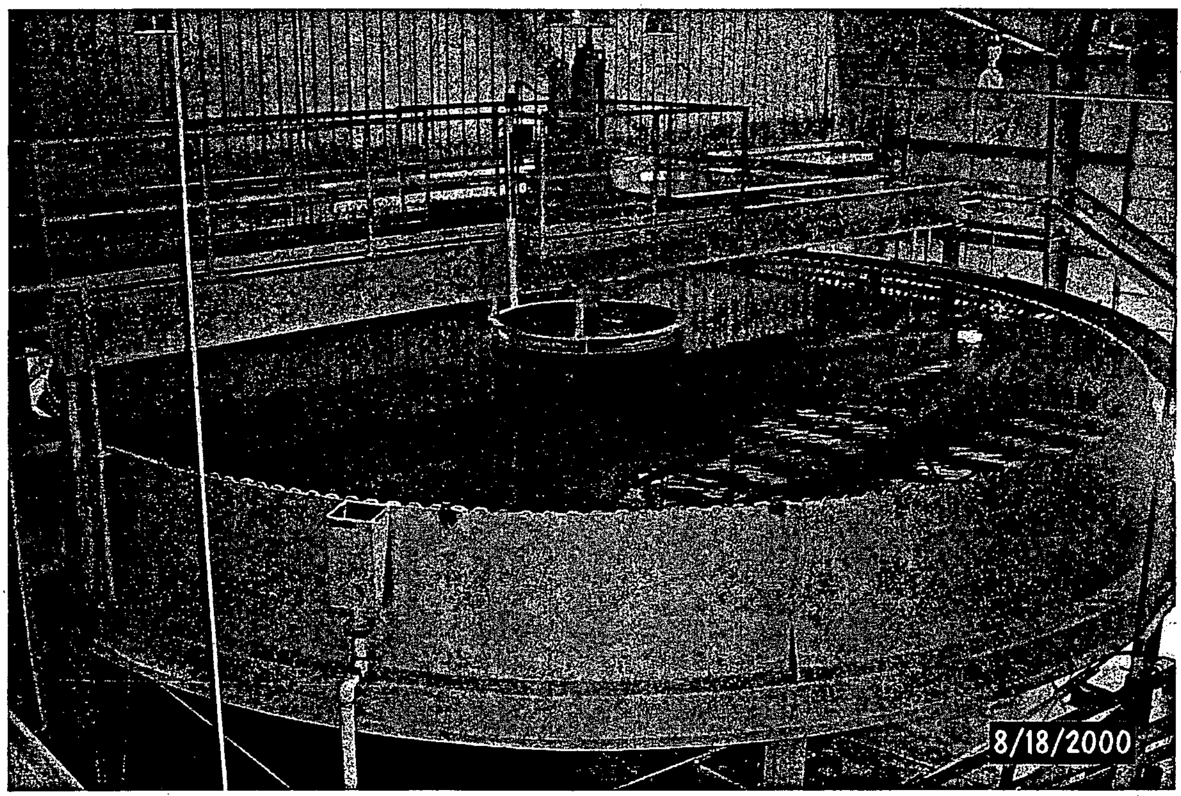

Figure 2.4-4. A Typical Thickener for an ISL Uranium Processing Facility

For onsite processing, the slurry is next dried in the yellowcake dryer. Historically, two kinds of yellowcake dryers have been used: multihearth dryers and vacuum dryers. Older uranium ISL facilities used gas-fired multi-hearth dryers. These dryers typically dry the yellowcake at about 400 to 620 °C [750 to 1,150 °F]. Because of the high temperatures involved, any organic contaminants in the yellowcake (e.g., grease from bearings) will be completely burned and will exit the system with the dryer offgas. This is advantageous because leftover organic residues in the packaged yellowcake product may oxidize while in the drum, causing the drum to pressurize and burst due to the evolution of gases (primarily CO_2) (NRC, 1999). The offgas discharge from the dryer is scrubbed with a high intensity venturi scrubber that is 95 to 99 percent efficient at removing uranium particulates before they are released to the atmosphere. Solutions from the scrubber are normally returned to the precipitation circuit and are processed to recover any uranium particulates. As a result, the stack discharge normally contains only water vapor and quantities of uranium fines that are managed to be below regulatory limits (see Section 2.7.1 and Chapter 8).

Newer ISL facilities usually use vacuum yellowcake dryers. In a vacuum dryer (Figure 2.4-5), the heating system is isolated from the yellowcake so no radioactive materials are entrained in the heating system or its exhaust. The drying chamber that contains the yellowcake slurry is under vacuum. Therefore, any potential leak would cause air to flow into the chamber, and the

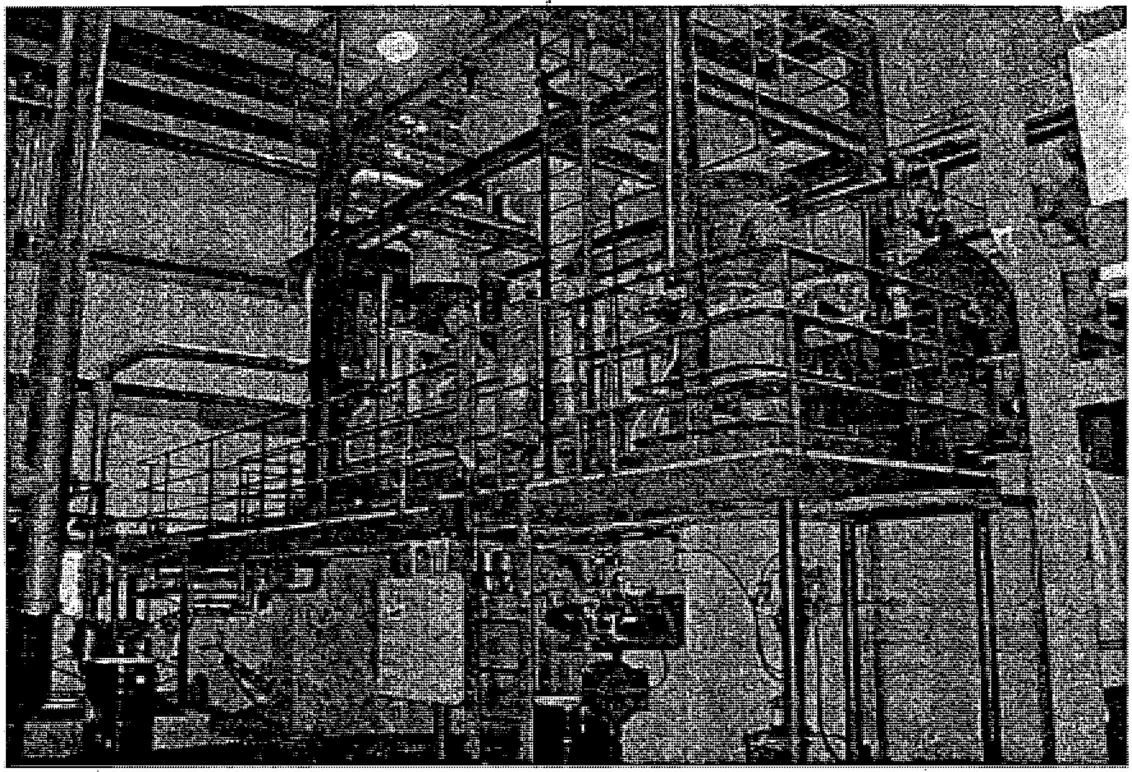

Figure 2.4-5. Typical Vacuum Dryer for Uranium Yellowcake Processing at an ISL Uranium Processing Facility

drying can take place at relatively low temperature {e.g., 149 °C [250 °F]}. Moisture in the yellowcake is the only source of vapor. Emissions from the drying chamber are normally treated in two ways. First, vapor passes through a bag filter to remove yellowcake particulates with an efficiency exceeding 99 percent. Any captured particulates are returned to the drying chamber. Second, any water vapor exiting the drying chamber is cooled and condensed. This process is designed to capture virtually all escaping particles (Mackin, et al., 2001a).

The dried product (yellowcake) is removed from the bottom of the dryer and packaged in drums for eventual shipping offsite. The packaging area normally has a baghouse dust collection system to protect personnel and to minimize yellowcake release. Air from the baghouse dust collection system is typically routed to the dryer offgas line and scrubber. During drum loading, the drum is normally kept under negative pressure via a drum hood with a suction line. The drum hood transports any released particulates to a baghouse dust collector. The filtered air from this baghouse joins the dryer offgas and is passed through the scrubber. Parameters important to the effective operation of the dryer must be monitored, and existing NRC regulations at 10 CFR Part 40, Appendix A, Criterion (8), prohibit dryer operations when these parameters are outside prescribed ranges. After the dried product is cooled, it is packaged and shipped in 208-L [55-gal] drums (Figure 2.4-6).

Figure 2.4-6. Labeled and Placarded 208-L [55-gal] Drum Used for Packaging and Shipping Yellowcake

2.4.3 Management of Production Bleed and Other Liquid Effluents

Uranium mobilization and processing produce excess water that must be properly managed. The production wells extract slightly more water than is re-injected into the host aquifer, which creates a net inward flow of groundwater in the well field. This production bleed is about 1 to 3 percent of the circulation rate, which can amount to an excess production of several tens to a hundred liters per minute (several tens of gallons per minute). As described in Section 2.4.1, the production bleed is diverted from the ISL circuit after the uranium is removed in the ion-exchange resin system, but before the lixiviant is recharged. This water still contains lixiviant and minerals leached from the aquifer. The excess water can be discharged to an evaporation pond or a deep well injection for disposal, or treated further for discharge to the environment (Section 2.7.2). Other liquid waste streams produced during ISL operation can include spent eluant from the ion-exchange system and liquids from process drains. These are handled in the same manner as the production bleed.

2.5 Aquifer Restoration

The purpose of aquifer restoration is to return well field water quality parameters to the standards in 10 CFR 40, Appendix A, Criterion 5(B)(5) or another standard approved by NRC

(NRC, 2009). Before ISL operations can begin, the portion of the aquifer designated for uranium recovery must be exempted as an underground source of drinking water, in accordance with the Safe Drinking Water Act (see Section 1.7.2.1). Groundwater adjacent to the exempted portion of the aquifer, however, must still be protected.

Prior to well field operations, applicants and licensees must determine baseline groundwater quality for the production zone (NRC, 2003a). In their applications, applicants or licensees identify the list of constituents to be sampled, which are typically similar to the NRC-accepted list of constituents shown in Table 2.2-1. Applicants or licensees may identify other constituents, or remove constituents, as long as a basis for the constituent(s) is provided and approved by NRC. State and other federal agencies with jurisdiction over groundwater could also specify constituents, which may or may not be included in the NRC-accepted list. In this case, the applicant would be accountable to the subject state or federal agency for characterizing and restoring these constituents.

To determine baseline water quality conditions prior to well field operations, applicants or licenses collect at least four sets of samples, spaced sufficiently in time to establish seasonal variability, and analyze the samples for the identified constituent (NRC, 2003a). An NRC-acceptable set of samples should include all well field perimeter monitoring wells and all upper and lower monitoring wells. Additionally, the applicant or licensee should sample at least one production/injection well per acre in the well field or enough production/injection wells to provide an adequate statistical population if fewer than one well per acre is used. NRC verifies the accuracy of baseline water quality data by ensuring that the applicant's or licensee's procedures include (1) acceptable sample collection methods, (2) a set of sampled parameters that is appropriate for the site and ISL extraction method, and (3) collection of sample sets that are sufficient to represent natural spatial and temporal variations in water quality.

After uranium recovery has ended, the groundwater in the well field contains constituents that were mobilized by the lixiviant. Licensees usually begin aquifer restoration in each well field soon after the uranium recovery operations end (NRC, 2008b). Aquifer restoration criteria for the site-specific baseline constituents are determined either on a well-by-well or well-field-by-well-field basis. NRC licensees are required to return water quality parameters to the standards in 10 CFR Part 40, Appendix A, Criterion 5B(5) or to another standard approved in their NRC license (NRC, 2009).

Aquifer restoration programs typically use a combination of methods including (1) groundwater transfer, (2) groundwater sweep, (3) reverse osmosis with permeate injection, (4) groundwater recirculation, and (5) stabilization monitoring (Energy Information Administration, 1995; Mackin, et al., 2001a; Davis and Curtis, 2007). NRC allows licensees the flexibility to select the restoration methods to be used for each well field (NRC, 2003a).

The EPA or state authorized to implement the EPA underground injection control program reviews any aquifer restoration plans for compliance with the applicable terms and conditions of the UIC permit requirements. NRC staff reviews any aquifer restoration plans for compliance with the NRC license to protect human health, safety, and the environment.

2.5.1 Groundwater Transfer

Groundwater transfer involves moving groundwater between the well field entering restoration and another well field where uranium leach operations are beginning, or alternately, within the

same well field, if one area is in a more advanced state of restoration than another (NRC, 2006). This technique displaces mining-affected waters in the restoration well field with baseline quality waters from the well field beginning leach operations. As a result, the groundwater in the two well fields becomes blended until the waters are similar in conductivity and therefore similar in the amount of dissolved constituents. Because water is transferred from one well field to another, groundwater transfer typically does not generate liquid effluents.

2.5.2 Groundwater Sweep

During groundwater sweep, the licensee pumps water from the well field to the processing plant through all production and injection wells without reinjection (Figure 2.5-1). This pumping causes uncontaminated, native groundwater to flow into the ore body, thereby flushing the contaminants from areas that have been affected by the horizontal spreading of the lixiviant in the affected zone during uranium recovery. Groundwater produced during the sweep phase will contain uranium and other contaminants mobilized during uranium recovery and residual lixiviant. The initial concentrations of these constituents would be similar to those during the uranium recovery operation phase, but would decline gradually with time (Davis and Curtis, 2007). The water removed from the aquifer during the sweep first is passed through an ion-exchange system to recover the uranium and then disposed either in evaporation ponds or via deep well injection in accordance with the limits in a UIC permit. The pumping rates used will depend on the hydrologic conditions at a given site, and the duration of the aquifer sweep

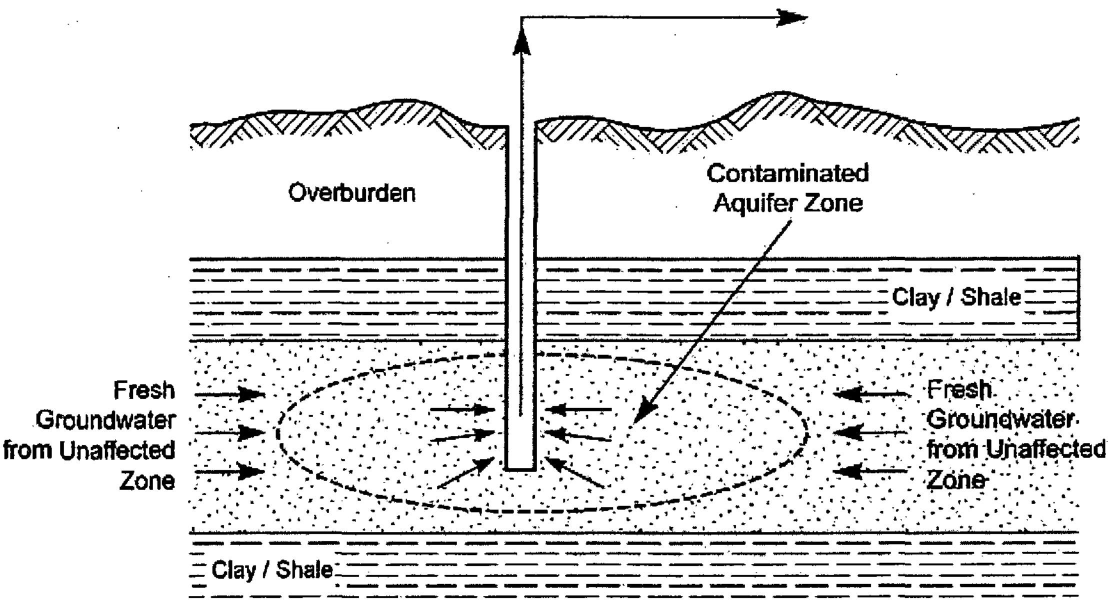

Figure 2.5-1. Schematic Diagram of Groundwater Sweep During Aquifer Restoration (After Energy Information Administration, 1995)

and volume of water removed depend on the volume of the aquifer affected by the ISL process. The aquifer volume typically is described in terms of "pore volumes" (see text box). Based on operational data (see Section 2.11.5), it is likely that more than one pore volume would be removed during the sweep. At the Crow Butte ISL facility in Dawes County, Nebraska, the pore volumes for the first six well fields {3.8 to 16.3 ha [9.3 to 40.2 acres]} were estimated to range from 58.3 to 298.7 million L [15.4 to 78.9 million gal] (NRC, 1998b). In comparison, the total pore volume for the nine well fields at the Irigaray Project was estimated to be 232.8 million L [61.5 million gal] (Cogema Mining, 2005).

2.5.3 Reverse Osmosis, Permeate Injection, and Recirculation

Reverse osmosis and permeate injection are used after groundwater sweep operations. This phase returns total dissolved solids, trace metal concentrations, and aquifer pH to baseline values (Davis and Curtis, 2007; NRC, 2003a). During permeate injection and recirculation, uranium in the groundwater is removed by passing the water through the ion-exchange circuit, as during operations. After that, other chemical constituents in the groundwater are removed by passing the groundwater through a reverse osmosis system consisting of pressurized, semipermeable membranes.

The reverse osmosis process yields two fluids: clean water (permeate: about 70 percent) that can be reinjected into the aquifer and water with concentrated ions (brine: about 30 percent) that cannot be reinjected directly. Water sent to the reverse osmosis system must be pretreated so the semipermeable membranes used in the system are not fouled. The pH is lowered, and additives called antiscalants are added to the groundwater upstream of the reverse osmosis unit to prevent precipitation of minerals (particularly calcium carbonate). Typically, sodium hexametaphosphate or polycarboxylic acid are used as antiscalants, and sulfuric acid is used for pH adjustment. After reverse osmosis, sodium hydroxide may be added to readjust the pH of the groundwater to baseline levels.

Pore Volume and Flare

Pore volume is a term used by the ISL industry to define an indirect measurement of a unit volume of aquifer water affected by ISL recovery. It represents the volume of water that fills the void space in a certain volume of rock or sediment. Pore volume provides a unit reference that an operator can use to describe the amount of lixiviant circulation needed to leach an ore body or describe the unit number of treated water circulations needed to flow through a depleted ore body to achieve restoration. A pore volume allows an operator to use relatively small-scale studies and scale the results to field-level pilot tests or to commercial well field scales. Typically, a "pore volume" is calculated by multiplying the surficial area of a well field (the area covered by injection and recovery wells) by the thickness of the production zone being exploited and the estimated or measured porosity of the aquifer material (NRC, 2003a).

A proportionality factor, known as "flare," is designed to estimate the amount of aquifer water outside of the pore volume that has been impacted by lixiviant flow during the recovery phase. The flare is usually expressed as a horizontal and vertical component to account for differences between the horizontal and vertical hydraulic conductivities of an aquifer material (NRC, 2003a).

The pumping and injection rates during this phase are likely to be similar to those during the sweep phase {hundreds of liters [gallons] per minute}, but depending on site hydrology, many pore volumes (often more than 10) may need to be circulated to achieve aquifer restoration goals (Davis and Curtis, 2007; Mackin, et al., 2001b). The net withdrawal from the aquifer depends on how the rejected liquid (reject) from the reverse osmosis system, which is about 30 percent of the pumping rate, is handled. Because the reject is a brine solution, it cannot be directly injected into the aquifer or discharged to the environment. The reject can be disposed directly in an evaporation pond or via a deep well injection in accordance with the discharge limits in a UIC permit. If the reject is sent directly to an evaporation pond or a deep disposal

well, the net withdrawal from the aquifer could be about 30 percent of the pumping rate {tens of liters [gallons] per minute}.

Alternatively, a brine concentrator can be used to treat the reject. The brine concentrator heats and evaporates the water, concentrating the brine, which then contains precipitated solids in the form of common salts. The brine concentration process typically results in about one part briny slurry and salts to 300 parts purified water. The purified water can be reintroduced into the aquifer, and thus the net withdrawal from the aquifer would be only a small percentage of the recirculation rate. The briny slurry is disposed in an evaporation pond or via deep well injection (Section 2.7.2).

After completing the reverse osmosis/permeate injection phase, the well field water will have characteristics similar to the permeate, and the recirculation phase takes place. To homogenize the groundwater, well field water may be circulated using the original injection and production wells. The quantity of water that is recirculated depends on site-specific baseline parameters and contaminant levels.

2.5.4 Stabilization

The purpose of the stabilization phase of aquifer restoration is to establish a chemical environment that reduces the solubility of dissolved constituents such as uranium, arsenic, and selenium. An important part of stabilization during aquifer restoration is metals reduction (Davis and Curtis, 2007). During uranium recovery, if the oxidized (more soluble) state is allowed to persist after uranium recovery is complete, metals and other constituents such as arsenic, selenium, molybdenum, uranium, and vanadium may continue to leach and remain at elevated levels. To stabilize metals concentrations, the preoperational oxidation state in the ore production zone should be reestablished as much as is possible. This is achieved by adding an oxygen scavenger or reducing agent such as hydrogen sulfide (H_2S) or a biodegradable organic compound (such as ethanol) into the uranium production zone during the later stages of recirculation (Davis and Curtis, 2007). The need for an aquifer stabilization phase will vary on a case-by-case basis, depending on how effectively the sweep and recirculation phases restore the affected aquifer to the required standards at a given site.

Following stabilization, the licensee monitors the groundwater by quarterly sampling to demonstrate that the approved standards for each parameter have been met and that any adjacent nonexempt aquifers are unaffected. As described in the case studies summarized in Davis and Curtis (2007), sampling at some sites after H_2S injection indicated that although reducing conditions were apparently achieved, they were not maintained over the longer term (see Section 2.11.5). The licensee would reinitiate aquifer restoration if stabilization monitoring determines it is necessary. Both the state permitting agency and the NRC must review and approve the monitoring results before aquifer restoration is considered to be complete.

2.6 Decontamination, Decommissioning, and Reclamation

Decommissioning an ISL facility is based on an NRC-approved decommissioning plan. This section discusses activities based on previous summaries (Energy Information Administration, 1995; Mackin, et al., 2001a). Details of decommissioning methods and criteria are provided in NUREG–1569, "Standard Review Plan for *In-Situ* Leach Uranium Extraction License Applications" (NRC, 2003a). Unless otherwise authorized by NRC, licensees are required under 10 CFR 40.42 to complete site decommissioning within 2 years from the time the

decommissioning plan has been approved. The primary steps involved in decommissioning an ISL facility include:

- Conducting radiological surveys of facilities, process equipment, and materials to evaluate the potential for exposure during decommissioning
- Removing contaminated equipment and materials for disposal at an approved facility or for reuse
- Decontaminating items to be released for unrestricted use
- Cleaning up areas used for contaminated equipment and materials
- Cleaning up evaporation ponds
- Plugging and abandoning wells
- Surveying excavated areas for contamination and removing contamination to meet cleanup limits
- Backfilling and recontouring disturbed areas
- Performing final site soil radiation background surveys
- Revegetating and reclaiming disturbed areas
- Monitoring the environment

Structures, waste materials, and equipment are surveyed to identify any radiation hazards. Materials that meet NRC unrestricted release criteria for surface contamination (NRC, 2003a, Sections 5.7.6.3 and 6.3) are segregated from those that do not meet the limits. Alternatives for handling process buildings and equipment include reuse, removal, or disposal. Contaminated items are decontaminated to meet release criteria (NRC, 2003a) if they are to be released for offsite unrestricted use; otherwise, they are disposed of as 11e.(2) byproduct material in a licensed disposal facility. Estimated volumes of building demolition and removed equipment wastes for an ISL facility are provided in Table 2.6-1. Waste volume estimates are provided for byproduct material wastes [requiring 11e.(2) licensed disposal] and municipal solid wastes (e.g., materials suitable for unrestricted release).

Pond liners and leak detection systems are surveyed. If radiological contamination is found, the liners and detection systems are typically removed and disposed in a licensed disposal facility. Estimated volumes of pond reclamation wastes for an ISL facility are provided in Table 2.6-1.

Well fields are decommissioned after groundwater restoration has been completed. Proper well field decommissioning protects the groundwater supply and eliminates physical hazards. First, surface equipment (such as injection and production lines), electrical components, and well head equipment (such as valves, meters, or fixtures) are salvaged. Then buried piping is removed, and the wells are plugged and abandoned using accepted practices identified as part of an EPA- or state-administered UIC program. NRC decommissioning inspection also visually verifies that well sealing and abandonment is done according to plans. Estimated volumes of well field decommissioning wastes for an ISL facility are provided in Table 2.6-1. The well field

Table 2.6-1. Estimated Decommissioning and Reclamation Waste Volumes (yd^3)* for Offsite Disposal, Smith Ranch *In-Situ* Leach Facility†

ISL Decommissioning Activity	Byproduct Waste	Municipal Solid Waste
Processing Equipment Removal	342	0
Building Demolition	546	531
Well Field Equipment	1,361	404
Trunk Line Removal	2,263	0
Contaminated Soil Removed	1,428	0
Evaporation Pond Reclamation	68	0

*To convert yd^3 to m^3, multiply by 0.7646.

†*Volumes were compiled and summed from an annual surety report.* McCarthy, J. "Smith Ranch: 2007–2008 Surety Estimate Revision." Letter (June 29) to G. Janosko, NRC. Glenrock, Wyoming: Power Resources International. 2007.

area is decontaminated in accordance with NRC regulatory limits at 10 CFR Part 40, Appendix A, and surveys are performed to ensure compliance with standards. Surface reclamation is completed using an NRC-approved plan.

Contaminated soils are cleaned up as necessary for decommissioning. Radiation surveys are conducted to determine whether any contaminated areas exist. Criteria at 10 CFR Part 40, Appendix A, are used for identifying contaminated soils and for determining when cleanup is complete. The NRC reviews and approves survey and sampling results. In the well fields where gamma radiation surveys correlate strongly with actual radiation concentrations in soil, (e.g., where contamination from leaks or spills of pregnant lixiviant would include uranium and daughter products including radium), gamma surveys are conducted as each well field unit is decommissioned. Soil samples are obtained from any areas that have elevated gamma readings. Areas contaminated with Ra-226, Ra-228, or other radionuclides exceeding the limits specified at 10 CFR Part 40, Appendix A, Criterion 6-(6), are cleaned up. Contaminated soil is removed and disposed as 11e.(2) byproduct material at a licensed disposal facility. The estimated volume of contaminated soil removal for an ISL facility is provided in Table 2.6-1. The most likely areas for contaminated soils are well field surfaces, evaporation pond bottoms and berms, process building areas, storage yards, transportation routes for uranium recovery products or contaminated materials, and pipeline runs. Areas used for land application of treated water are also surveyed and decontaminated as necessary.

All radioactive wastes generated during ISL facility decommissioning (as well as radioactive wastes generated during operations and aquifer restoration) are considered 11e.(2) byproduct material that must be disposed at a licensed facility (Section 2.7).

An NRC-approved surface reclamation plan ensures disturbed lands are returned to near preconstruction or to planned postoperational land use. Baseline data on soils, vegetation, wildlife, and radiation are used as guidelines for the surface reclamation. Areas disturbed by the uranium recovery operations are restored as closely as possible to preoperational conditions. Reclamation activities include replacing excavated soils, recontouring affected areas, reestablishing original drainage, and revegetation. The magnitude of reclamation activities varies, in part, with the size of the ISL facility. A large ISL facility, Smith Ranch (see Table 2.11-1) has estimated the need to apply approximately 43,748 m^3 [57,221 yd^3] of topsoil to the ground surface during site reclamation (McCarthy, 2007). Because topsoil excavated during construction was stockpiled and reseeded to limit erosion (NRC, 1992), the net amount of topsoil needed to replace topsoil removed during decommissioning is approximated by the

estimated volume of excavated soil destined for offsite disposal shown in Table 2.6-1 {1,092 m^3 [1,428 yd^3]}. After reclamation is complete, lands are normally capable of supporting wildlife and uses such as livestock grazing.

Financial surety arrangements (Section 2.10), established when an NRC license is granted, provide assurance that the costs of aquifer restoration and site decommissioning are covered when facility operations end. The surety also covers costs to close the site at any point during operations.

2.7 Effluents and Waste Management

ISL facilities generate airborne effluents, liquid wastes, and solid wastes that must be handled and disposed of properly. Effluents, waste streams, and waste management practices applicable to ISL facilities are described in this section. Transportation of wastes is discussed in Section 2.8.

2.7.1 Gaseous or Airborne Particulate Emissions

During construction, operations, aquifer restoration, and decommissioning, ISL facilities can produce airborne emissions including

- Fugitive dusts
- Combustion engine exhausts
- Radon gas emissions from lixiviant circulation and evaporation ponds
- Uranium particulate emissions from yellowcake drying

Fugitive dusts and engine exhausts are generated primarily during construction, transportation, and decommissioning activities. The fugitive dust is generated by travel on unpaved roads and from disturbed land associated with the construction of well fields, roads, and support facilities. Vehicles workers use to commute to the facility, to support onsite activities, to transport supplies to the site, or to transport product and wastes away from the site emit fuel combustion products. Diesel emissions originate from drill rigs, diesel-powered water trucks, and other equipment used during the construction phase. Operations rely on trucks for supply shipments and to transport product and some waste materials away from the site. Decommissioning activities produce emissions from construction equipment and from trucks used to haul waste materials offsite. Table 2.7-1 provides information from a previously licensed ISL satellite facility on the nature and duration of nonradiological emission-generating activities during construction, operation, and decommissioning. Table 2.7-2 contains the annual total releases and average air concentrations of particulate (fugitive dust) and gaseous (diesel combustion products) emissions estimated for the construction phase of the ISL facility near Crownpoint, New Mexico.

Radon gas is released during operation and aquifer restoration. Pressurized processing systems may contain most of the radon in solution; however, radon may escape from the processing circuit in the central uranium processing facility through vents or leaks, during well field operations, or during resin transfer when remote ion-exchange is used. For open air activities, the gas quickly disperses into the air. In closed processing areas, the building ventilation systems are designed to limit indoor radon concentrations. Radon detectors are placed in appropriate locations to ensure compliance with worker protection regulations in 10 CFR Part 20. Airborne particulate emissions from yellowcake drying and packaging and the filling of sodium bicarbonate storage containers are controlled by using vacuum drying

Table 2.7-1. Combustion Engine Exhaust Sources for the Gas Hills *In-Situ* Leach Satellite Facility During Construction, Operations, Reclamation, and Decommissioning*

Period	Activity	Equipment Type	Number of Units	Frequency of Operation	Duration of Operation
Construction	Initial Construction/ Well Field Road Construction	Scraper	1	8 hr/day, 5 day/wk	2 months
		Bulldozer	1	"	"
		Motor Grader	1	"	"
	Well Preparation	Truck Mount Rotary Drill Rig, Diesel Truck	4-8	8 hr/day, 5 day/wk	12 mo/yr
		Pump Pulling Vehicle 1-ton gas or diesel	2	"	"
		Motor Grader	1	"	3 mo/yr
		Backhoe	3	"	12 mo/yr
		Forklift	2	"	"
		Cementer (gas)	4	"	"
		Light Duty Truck	8-10	8 hr/day, 7 day/wk	"
	Construction Material Transport	Heavy Duty Water Truck (1,500 gal)	4-8	"	"
		Heavy Duty Diesel Truck	1	1 trip/day	2 mo/yr
	Commuting	Light Duty Vehicles	30	"	6 mo/yr
Operation	Satellite Facility	Gas or Propane Heater	6	24 hr/day	6 mo/yr
	Product Transport	Truck to Highland Site Diesel Semi with Trailer	2	1 trip/day	12 mo/yr
	Commuting	Light Duty Vehicles	30	"	"
Decommissioning	Reclamation	Scraper	1	2 × 8 hr shift/day*	2-3 yr
		Motor Grader	1	"	"
		Backhoe	2	"	"
		Heavy Duty Truck (Diesel)	3	"	"
		Light Duty Truck	15	"	"
		Light Duty Vehicles	20	1 trip/day	"

*NRC. "Environmental Assessment for the Operation of the Gas Hills Project Satellite In-Situ Leach Uranium Recovery Facility." Docket No. 40-8857. Washington, DC: NRC. January 2004.

Table 2.7-2. Estimated Particulate (Fugitive Dust) and Gaseous (Diesel Combustion Products) Emissions for the Crownpoint, New Mexico, *In-Situ* Leach Facility Construction Phase*

Emission Type	Annual Total (metric tons)†	Annual Average Concentration (μg/m³)‡
Particulates	10.0	0.28
Sulfur dioxides (SO_x)	6.4	0.18
Nitrous oxides (NO_x)	76.2	2.1
Hydrocarbons	9.8	0.27
Carbon monoxide	63.7	1.8
Aldehyde	1.4	0.04

*Modified from U.S. Nuclear Regulatory Commission. NUREG–1508, "Final Environmental Impact Statement To Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico." Washington, DC: U.S. Nuclear Regulatory Commission. February 1997.

†Multiply metric ton value by 1.1023 to convert units to short ton.

‡Multiply μg/m³ value by 2.74×10^{-8} to convert units to oz/yd³.

equipment, wet scrubbers, or baghouse dust collection systems. The use of vacuum drying equipment at ISL facilities significantly reduces uranium releases from drying operations (NRC, 2003a).

Both radon releases and uranium particulate emissions can migrate downwind from processing facilities and well fields. Downwind radiation dose from such ISL facility emissions varies due to the effects of dispersion as a function of distance. Particulate emissions are further reduced by the effect of dry deposition during airborne transport. Calculations of downwind dose are based on estimating the relative air concentration of released radionuclides (which is proportional to dose). Figure 2.7-1 shows relative air concentration for particulate matter as a function of distance estimated for the Bison Basin ISL facility (NRC, 1981, Table D.3). These results apply to the downwind area with the highest relative air concentrations. As shown, relative air concentration of uranium particulates, and therefore dose, drops by about a factor of 10 from the first data point {500 m [1,640 ft]} to the second {1,500 m [4,920 ft]}. The reduction in relative air concentration, and therefore dose, becomes less significant as downwind distance increases. The effect of distance on air concentration estimates is less pronounced for transport of gases (e.g., radon) due to the absence of dry deposition, which does not apply to gaseous transport. Airborne transport and dose modeling results for ISL facility releases to air (including both radon and uranium particulate releases, where applicable) are provided in Sections 4.2.11.2, 4.3.11.2, 4.4.11.2, and 4.5.11.2.

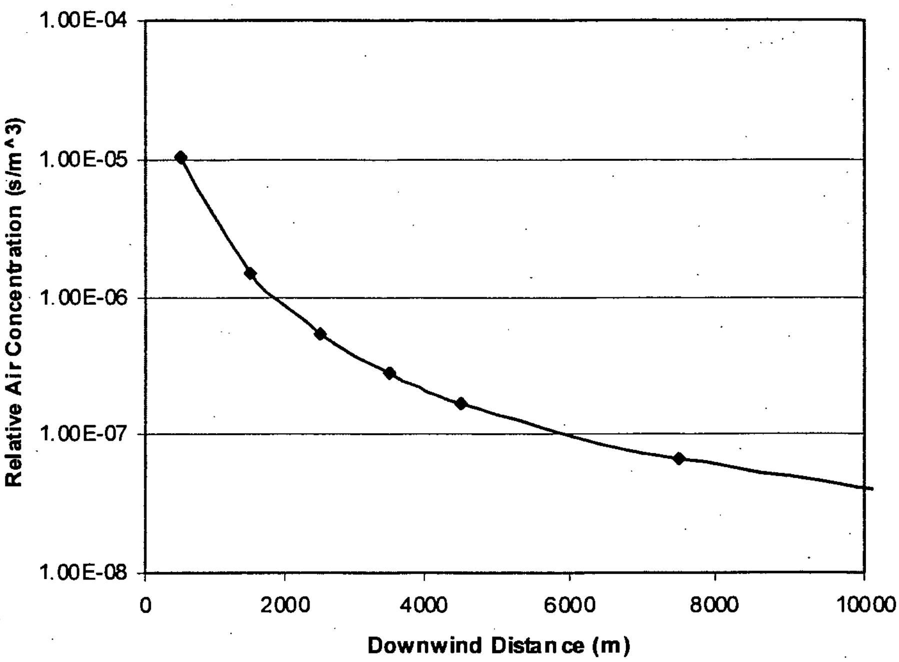

Figure 2.7-1. Downwind Distance Versus Relative Air Concentration (Which Is Proportional to Dose) [Bison Basin ISL Facility (NRC, 1981, Table D.3)]

2.7.2 Liquid Wastes

Liquid wastes from ISL facilities are generated during all phases of uranium recovery; construction, operations, aquifer restoration, and decommissioning. Liquid wastes may contain elevated concentrations of radioactive and chemical constituents. Table 2.7-3 shows estimated flow rates and constituents in liquid waste steams for the Highland ISL facility (NRC, 1978). Liquid waste streams are predominantly production bleed (1 to 3 percent of the process flow rate) and aquifer restoration water (NRC, 1997a). Additional liquid waste streams are generated from well development, flushing of depleted eluant to limit impurities, resin transfer wash, filter washing, uranium precipitation process wastes (brine), and plant wash down water.

ISL facilities have concrete curbed floors with drains and a sump to control and retain water from spills and wash downs. Sumps direct water to treatment facilities, to evaporation ponds, or back to the process circuit. Chemical tanks have berms that can hold tank contents if tanks rupture.

Some liquid wastes are treated at the processing facility to remove or reduce contaminants prior to disposal. Reverse osmosis is commonly used to segregate contaminants from liquid waste streams (e.g., Section 2.5.3). Radium concentrations are also selectively reduced when water is treated with barium chloride. The barium chloride chemically binds to radium in solution and deposits as a sludge that is sent to a licensed disposal facility. Results from Hydro

Table 2.7-3. Estimated Flow Rates and Constituents in Liquid Waste Streams for the Highland *In-Situ* Leach Facility*

	Water Softener Brine	Resin Rinse	Elution Bleed	Yellowcake Wash Water	Restoration Wastes
Flow Rate, gal/min	1	<3	3	7	450
As, ppm					0.1–0.3
Ca, ppm	3,000–5,000				
Cl, ppm	15,000–20,000	10,000–15,000	12,000–15,000	4,000–6,000	
CO_3, ppm		500–800			300–600
HCO_3, ppm		600–900			400–700
Mg, ppm	1,000–2,000				
Na, ppm	10,000–15,000	6,000–11,000	6,000–8,000	3,000–4,000	380–720
NH_4, ppm			640–180		
Se, ppm					0.05–0.15
Ra-226, pCi/L	<5	100–200	100–300	20–50	50–100
SO_4, ppm					100–200
Th-230, pCi/L	<5	50–100	10–30	10–20	50–150
U, ppm	<1	1–3	5–10	3–5	<1
Gross Alpha, pCi/L					2,000–3,000
Gross Beta, pCi/L					2,500–3,500

*NRC. NUREG–0489, "Final Environmental Statement Related to Operation of Highland Uranium Solution Mining Project, Exxon Minerals Company, USA." Washington, DC: NRC. November 1978.

Resources, Inc. reported in NRC (1997a) show radium concentrations of 74 pCi/l were reduced to less than 1 pCi/L following treatment with barium chloride.

Liquid effluent disposal practices that NRC previously has approved for use at specific sites include evaporation ponds, land application, deep well injection, and surface water discharge.

Evaporation ponds are used to retain the process-related liquid effluents that cannot be discharged directly to the environment. These effluents are 11e.(2) byproduct material. The residual solid waste materials normally remain in ponds until the ponds are decommissioned, when sludges are disposed of as 11e.(2) material at a licensed disposal facility (Section 2.6). Guidance for the construction, operation, and monitoring of evaporation ponds is found in NRC Regulatory Guide 3.11 (NRC, 2008a). Typical evaporation ponds have surface areas ranging from 0.04 to 2.5 ha [0.1 to 6.2 acres] (NRC, 1998a; Crow Butte Resources, 2007). Evaporation ponds at NRC-licensed ISL facilities are designed with leak detection systems to detect liner failures. The licensee also must maintain sufficient reserve capacity in the retention pond system so the contents of a pond can be transferred to other ponds in the event of a leak and subsequent corrective action and liner repair. Licensees and applicants can minimize the likelihood of impoundment failure by designing the pond embankments in accordance with the criteria found in NRC Regulatory Guide 3.11 (NRC, 2008a). Sufficient freeboard height above the liquid level ensures containment during wind and rain events.

Land application uses agricultural irrigation equipment to apply treated water to land where the water can evaporate directly or be transpired by plants. Uranium and radium levels are reduced in the effluents disposed of by land application so as to limit contamination of surface soils and plants. Land application may also require approval and permitting by other state agencies. Areas of a site where land application of treated water takes place are included in environmental monitoring programs required by NRC and Sate regulators to ensure constituents of interest including uranium, radium, and selenium are maintained below levels of concern. Land application areas are also included in decommissioning surveys at the end of operations to ensure soil concentration limits are not exceeded.

Deep well injection involves pumping the waste fluids into a deep confined aquifer at depths typically greater than 1,524 m [5,000 ft] below the ground surface (NRC, 1997a). Aquifer water quality in the deep confined aquifer is often poor (e.g., high salinity or total dissolved solids) and below drinking water standards. NRC staff reviews and approves deep well injection as a method to dispose of particular process fluids such as reverse osmosis brine. As discussed in Section 1.7, a UIC permit from EPA or the appropriate state agency is required for a licensee to use this method of waste disposal at a specific site. These reviews by NRC and other agencies ensure that the disposal of wastes by this method complies with the dose limits in 10 CFR Part 20 and with appropriate National Pollutant Discharge Elimination System (NPDES) permit conditions. The approval process verifies that site-specific and regional characteristics limit the potential for contamination of local drinking water sources.

The discharge of pollutants to surface water requires an NPDES permit (Section 1.8). This permit specifies limits that are calculated to ensure the discharge does not cause a violation of water quality standards. A permit will not be issued to a new source or a new discharger if the discharge will cause or contribute to the violation of water quality standards. Specific requirements for uranium ISL facilities are provided in EPA regulations at 40 CFR Part 440, Part C.

2.7.3 Solid Wastes

All phases of the ISL facilities lifecycle generate solid wastes. These separate waste streams can produce materials that can be classified as 11e.(2) byproduct, ordinary municipal solid waste, and Resource Conservation and Recovery Act (RCRA) hazardous wastes. Radioactive wastes generated by ISL facilities are defined as 11e.(2) byproduct material by NRC. Unless suitable to remain onsite or to be released offsite for unrestricted use, 11e.(2) byproduct material wastes must be disposed at a facility that is licensed to accept byproduct waste. ISL facilities also generate normal trash (i.e., solid waste) that would be disposed at a local landfill. Some RCRA hazardous wastes (e.g., fluorescent lights, waste oil, and batteries) would be generated at an ISL facility, thereby requiring disposal at a facility approved for RCRA hazardous wastes. Soils in areas where ISL operations occur would be included in decommissioning surveys when operations end, and any contaminated soils that exceed NRC release limits at 10 CFR Part 40, Appendix A, Criterion 6 would be removed and disposed of as 11e.(2) byproduct waste. The largest volumes of solid wastes requiring disposal are generated during facility decommissioning (EPA, 2007a,b). Table 2.6-1 provides estimated volumes of byproduct and other solid ISL facility decommissioning wastes designated for offsite disposal.

2.8 Transportation

Trucks transport construction equipment and materials, operational processing supplies, ion-exchange resins, yellowcake product, and waste materials during all phases of an ISL facility lifecycle.

Construction equipment and materials are transported along local roads to the site to support facility and well field construction activities. Because ISL facilities are small magnitude construction projects, and well field construction is phased over a period of years, the magnitude of trucking activity to support construction is small relative to other industrial activities. The estimated frequency of truck shipments for construction of an ISL facility is provided in Table 2.8-1.

During the operational period, trucks supply an ISL facility with materials needed to support processing operations. Shipments involve hazardous chemicals such as ammonia, sulfuric acid, liquid and gaseous oxygen, hydrogen peroxide, sodium hydroxide, barium chloride, carbon dioxide, hydrochloric acid, sodium carbonate, sodium chloride, hydrogen sulfide, and sodium sulfide. These chemicals are commonly used in a variety of industrial applications, and the U.S. Department of Transportation regulates their transport. The estimated frequency of truck shipments to support ISL facility operation is provided in Table 2.8-1.

In areas where ore deposits are smaller and more spread out, a producer may construct a series of small satellite plants at the well field where ion-exchange processing is conducted remotely rather than at the central uranium processing facility (NRC, 2004a, 2006). The products of ion-exchange processing are then transported by truck to a central uranium processing facility (Section 2.4). Uranium production using these types of satellite facilities is sometimes known as satellite remote ion exchange (Finch, 2007). Facilities that incorporate remote ion-exchange operations will transport loaded ion-exchange resins or uranium slurry from well fields to centralized processing facilities by truck. These trucks are typically modified three-compartment cement trailers. The carbon steel compartments are pressurized and rubber lined. The first compartment carries the uranium-loaded resin, the second is empty, and the third compartment holds unloaded resins (Finch, 2007). Each shipment can contain about

Table 2.8-1. Estimated Annual Vehicle Trips for Phases of *In-Situ* Leach Facility Lifecycle

Cargo	Estimated Number of Truck Shipments	Remarks
Construction Equipment/Supplies	62*	1 per day for 2 months
Remote IX Shipments	365*	1 per day annually
Processing Chemicals	272†	Less than 1 per day annually
Processing Wastes	Range: 2.5–15*	Less than 1 per month annually
Yellowcake	Range: 21–145‡§‖¶#	Maximum is based on production assumed at the permitted limit at the largest facility
Decommissioning Municipal Solid Waste	44**	Based on waste volumes from Smith Ranch (Table 2.6-1) and truck volume of 20 yd^3/shipment
Decommissioning Byproduct Waste	100**	Based on waste volumes from Smith Ranch (Table 2.6-1) and truck volume of 20 yd^3/shipment
Employee Commuting	5,200–52,000 trips*	20 to 200 employees per day assumed for 12 months/yr. Maximum in range is expected to depend on timing of construction, drilling, and operational activities (Section 2.11.6)

*NRC. "Environmental Assessment for the Operation of the Gas Hills Project Satellite *In-Situ* Leach Uranium Recovery Facility." Docket No. 40-8857. Washington, DC: NRC. January 2004.

†NRC. "Environmental Assessment for Renewal of Source Material License No. SUA–1534—Crow Butte Resources Inc., Crow Butte Uranium Project Dawes County, Nebraska." Docket No. 40-8943. Washington, DC: NRC. 1998.

‡NRC. NUREG–0489, "Final Environmental Statement Related to Operation of Highland Uranium Solution Mining Project, Exxon Minerals Company, USA." Washington DC: NRC. November 1978.

§NRC. "Final Environmental Statement Related to the Operation of Bison Basin Project." Docket No. 40-8745. Washington, DC: NRC. 1981.

‖NRC. NUREG–1508, "Final Environmental Impact Statement To Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico." Washington, DC: NRC. February 1997.

¶NRC. "Environmental Assessment for Renewal of Source Material License No. SUA–1534—Crow Butte Resources Inc., Crow Butte Uranium Project Dawes County, Nebraska." Docket No. 40-8943. Washington, DC: NRC. 1998.

#NRC. "Environmental Assessment Construction and Operation of In Situ Leach Satellite SR-2 Amendment No. 12 to Source Material License No. SUA-1548—Power Resources, Inc., Smith Ranch-Highland Uranium Project (SR-HUP) Converse County, Wyoming." Docket No. 40-8964. Washington DC: NRC. December 2007.

**Waste volumes compiled and summed from estimates reported in McCarthy, J. "Smith Ranch: 2007–2008 Surety Estimate Revision." Letter (June 29) to G. Janosko, NRC. Glenrock, Wyoming: Power Resources International. 2007.

900–1,350 kg [2,000–3,000 lb] of uranium-loaded resin, although the actual amount depends on the size of the trailer. These trucks are generally sole-use vehicles that are labeled for this purpose in accordance with U.S. Department of Transportation requirements at 49 CFR 171–189 and NRC regulations at 10 CFR Part 71. In accordance with these regulations, no liquids are permitted in the truck during transport of uranium resins. The estimated frequency of remote ion-exchange truck shipments to support ISL facility operation is provided in Table 2.8-1. The distance of remote ion-exchange shipments varies depending on

site characteristics. For example, the Irigaray/Christensen Ranch ISL facility in Johnson County, Wyoming, has shipped ion-exchange resins 21 km [13 mi] (NRC, 1998a), whereas the Gas Hills ISL facility in Natrona and Freemont Counties in Wyoming has shipped ion-exchange resins about 224 km [140 mi] (NRC, 2004b).

The refined yellowcake product is packed in 208-L [55-gal], 18-gauge drums holding an average of 430 kg [950 lb] and classified by the U.S. Department of Transportation as Type A packaging (49 CFR Parts 171–189 and 10 CFR Part 71). The yellowcake is shipped by truck to a remote conversion plant that transforms the yellowcake to uranium hexafluoride (UF_6) for the enrichment step of the reactor fuel cycle. An average truck shipment contains approximately 40 drums or 17 metric tons [19 short tons] of yellowcake (NRC, 1980). The annual number of shipments from a given ISL facility depends on the yellowcake production rate of the facility. A range of estimated annual shipment totals based on prior ISL facility production limits is provided in Table 2.8-1.

Waste materials generated by construction, operation, aquifer restoration, and decommissioning activities, including byproduct and ordinary municipal waste streams, are segregated by waste type and transported by truck to approved disposal facilities. The estimated frequency of waste shipments for operation and decommissioning an ISL facility is provided in Table 2.8-1. Section 2.7 provides additional information on waste streams and waste management activities.

2.9 Radiological Health and Safety

NRC regulations at 10 CFR Part 20 address the health and safety of workers and the public in the event of exposure to radiation from all phases of an ISL facility's lifecycle. These regulations require ISL facility operators to develop and implement an NRC-approved radiation protection program. During NRC inspections and other oversight activities, including reviews of monitoring and incident reports, NRC checks compliance with this program. This section briefly summarizes basic elements of a 10 CFR Part 20 radiation protection program. More detailed descriptions of radiological safety requirements and programs are found in the regulations at 10 CFR Part 20 and applicable NRC guidance documents summarized in the NRC Standard Review Plan for ISL facilities (NRC, 2003a).

Uranium recovery facilities are also subject to the EPA's environmental standards for the uranium fuel cycle, in 40 CFR Part 190, which provide an annual dose limit of 0.25 mSv (25 mrem) whole body (plus limits for organ doses) from fuel cycle operations, but not including dose due to radon and its progeny.

A 10 CFR Part 20 radiological protection program includes plans and procedures addressing the following topics:

- **Effluent Control**. Effluents to air (e.g., radon, uranium particulates) and surface water (e.g., permitted wastewater discharges) must meet NRC limits in 10 CFR Part 20 for radioactive effluents and worker and public doses. To ensure proper performance to specifications, plans and procedures include minimum performance specifications for control technologies (e.g., yellowcake dryer emission controls) and frequencies of tests and inspections.

- **External Radiation Exposure Monitoring Program.** This program specifies survey methods (including monitoring locations), instrumentation, and equipment for measuring worker exposures to external radiation during routine and nonroutine operations, maintenance, and cleanup activities. The program is designed to ensure worker dose levels are as low as reasonably achievable and comply with NRC requirements in 10 CFR Part 20.

- **Airborne Radiation Monitoring Program.** This program determines concentrations of airborne radioactive materials (including radon) in the workplace during routine and nonroutine operations, maintenance, and cleanup. This program is designed to ensure airborne radiation releases and worker exposures are as low as reasonably achievable and meet requirements specified in 10 CFR Part 20.

- **Exposure Calculations.** Procedures document the methodologies used to calculate intake of airborne radioactive materials in the workplace during routine and nonroutine operations, maintenance, and cleanup activities.

- **Bioassay Program.** A bioassay program assesses biological intake of uranium by workers routinely involved in operations where radioactive material can be inhaled (e.g., yellowcake dust from dryer operations or baghouse maintenance). Programs include collection and analysis of urine samples that are assessed for the presence of uranium. Action levels are set to maintain exposures as low as reasonably achievable and within worker requirements in 10 CFR Part 20.

- **Contamination Control Program.** A contamination control program includes standard operating procedures to prevent employees from entering clean areas or leaving the site while contaminated with radioactive materials. Such programs involve radiation surveys of personnel and surfaces, housekeeping requirements, specifications to control contamination in processing areas, and controls for the release of contaminated equipment.

- **Environmental Monitoring Program.** This program measures concentrations and quantities of radioactive and nonradioactive materials released to the environment surrounding the facility. Such programs measure concentrations of constituents in the environment near and beyond the site boundary emphasizing surface water, groundwater, vegetation, food and fish, and soil and sediment. Direct radiation and radon are also measured. Offsite radiological and environmental monitoring is detailed in Chapter 8.

2.10 Financial Surety

NRC regulations [10 CFR Part 40, Appendix A, Criterion (9)] require that applicants or licensees cover the costs to conduct decommissioning, reclamation of disturbed areas, waste disposal, and groundwater restoration (Mackin, et al., 2001b). NRC annually reviews a licensee's financial surety to assess expansions in operations, changes in engineering design, completion of decommissioning activities, actual experience in aquifer restoration, and inflation. Specific considerations for estimating these costs are detailed in Appendix C of NRC, 2003a, and financial surety arrangements are discussed only briefly here.

Each licensee establishes financial surety arrangements before uranium recovery operations begin to assure there will be sufficient funds to carry out the activities described in Sections 2.5 and 2.6. The surety funds also must be sufficient for monitoring and control required as part of the license termination. Acceptable financial surety arrangements include surety bonds, cash deposits, certificates of deposit, deposits of government securities, parent company guarantees (subject to specific NRC criteria), trusts and standby trusts, irrevocable letters or lines of credit, and combinations of these instruments. Self-insurance is not an acceptable form of surety for NRC, although it may be accepted by individual states. The term of the surety mechanism must be open ended so that it will not expire before cleanup is complete.

As required under 10 CFR Part 40, Appendix A, Criterion 9, the licensee must supply enough information for NRC to verify that the amount of financial coverage will allow all decontamination and decommissioning and reclamation of sites, structures, and equipment used in conjunction with facility operation to be completed. Cost estimates for the following activities (where applicable) should be submitted to NRC with the initial license application or reclamation plan and should be updated annually as specified in the operator's NRC license. The financial surety estimate must include calculations of cost estimates based on completion of all activities by a third-party contractor (an independent contractor or operator who is not financially affiliated with the licensee), if necessary. Unit costs, calculations, references, assumptions, equipment and operator efficiencies, and other breakdown details must be provided.

In the required annual surety estimate, the licensee should add a contingency amount to the total cost estimate for the final site closure. NRC typically considers a 15 percent contingency to be an acceptable minimum amount (NRC, 2003a, Appendix C). The licensee is required by 10 CFR Part 40, Appendix A, Criterion 9, to adjust cost estimates annually to account for inflation and changes in reclamation plans. In addition, all costs are to be estimated based on third party, independent contractor costs (including overhead and profit in unit costs or as a percentage of the total). Licensee-owned equipment and the availability of licensee staff should not be considered in the financial surety estimate, because this can reduce cost calculations.

To avoid unnecessary duplication and expense, NRC also takes into account surety arrangements that other federal, state, or other local agencies may require. However, NRC is not required to accept such sureties if they are insufficient. NRC reviews the licensee's surety analysis annually to ensure that the funding reflects ongoing aquifer restoration and decommissioning/reclamation activities. The surety remains in place until the final NRC decommissioning surveys are complete and the license is terminated.

2.11 Information From Historical Operation of ISL Uranium Milling Facilities

2.11.1 Area of ISL Uranium Milling Facilities

The permitted areas for past and current ISL uranium recovery operations have varied in size. As shown in Table 2.11-1, facilities range from about 1,034 ha [2,552 acres] for the proposed Crownpoint facility in McKinley County, New Mexico, to more than 6,480 ha [16,000 acres] for the Smith Ranch property in Converse County, Wyoming. The central processing facility may occupy only 1 to 6 ha [2.5 to 15 acres], and satellite plants would be even smaller (NRC, 2006). Surface facilities are considered controlled areas where security fencing limits access. Select areas around header houses and well heads are fenced to prevent livestock grazing. Lands

near surface operations and in active uranium recovery are excluded from agricultural production for the duration of the project.

Table 2.11-1. Size of Permitted Areas for *In-Situ* Leach Facilities		
Name	**Permitted Area in Hectares [acres]**	**Status of Facility as of February 2008**
Crownpoint, New Mexico	1,034 [2,552]*	Partially permitted and licensed
Crow Butte, Nebraska	1134 [2,800] †	Operating
Gas Hills, Wyoming (Satellite)	3,442 [8,500]‡	Under development as a satellite of Smith Ranch/Highland, intend to expand
Reynolds Ranch, Wyoming (Satellite	3,525 [8,704]§	Under development as satellite of Smith Ranch/Highland
Highland, Wyoming	6,075 [15,000] ‖	Operating, combined with Smith Ranch
Irigaray, Christensen Ranch	6,075 [15,000]¶	Licensed to restart operations
Smith Ranch, Wyoming	6,480 [16,000]#	Operating, combined with Highland, Gas Hills, North Butte, and Ruth, intend to expand

*NRC. NUREG–1508, "Final Environmental Impact Statement To Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico." Washington, DC: NRC. February 1997.
†NRC. "Environmental Assessment for Renewal of Source Material License No. SUA–1534—Crow Butte Resources Inc., Crow Butte Uranium Project Dawes County, Nebraska." Docket No. 40-8943. Washington, DC: NRC. 1998.
‡NRC. "Environmental Assessment for the Operation of the Gas Hills Project Satellite *In-Situ* Leach Uranium Recovery Facility." Docket No. 40-8857. Washington, DC: NRC. January 2004.
§NRC. "Environmental Assessment for the Addition of the Reynolds Ranch Mining Area to Power Resources Inc., Smith Ranch/Highlands Uranium Project Converse County Wyoming, Source Material License No SUA–1548." Docket No. 40-8964. Washington, DC: NRC. November 2006.
‖NRC. "Environmental Assessment for Renewal of Source Material License No. SUA-1511 Power Resources Inc., Highland Uranium Project Converse County, Wyoming." Docket No. 40-8857. Washington DC: NRC. August 18, 1995.
¶NRC. "Environmental Assessment for Renewal of Source Material License No. SUA–1341, Cogema Mining, Inc. Irigaray and Christensen Ranch Projects, Campbell and Johnson Counties, Wyoming." Docket No. 40-8502. Washington, DC: NRC. June 1998.
#NRC. "Environmental Assessment for Rio Algom Mining Corporation Smith Ranch *In-Situ* Leach Mining Project, Converse County, Wyoming in Consideration of a Source and Byproduct Material License Application." Docket No. 40-8964. Washington, DC: NRC. January 1992.

Much of the permitted area of a site is undisturbed, and surface operations (wells, processing facilities) affect only a small portion of it. The well fields, which include the injection and recovery (production) wells, are the areas where most activities that disturb the surface and subsurface take place. Less than half of the surface area allocated to well fields is expected to be disturbed by construction activities including access roads, drilling pits, header houses, and pipelines (NRC, 1995). Estimates of the amount of surface area disturbance reported for five NRC-licensed ISL facilities vary and range from 49 to 750 ha [120 to 1,860 acres] (NRC, 1998a,

1997a, 1992, 1987; Crow Butte Resources, Inc., 2007). These disturbed areas constitute approximately 1 to 70 percent of the permitted areas of the sites with an average of 15 percent of the permitted area disturbed among the five facilities. Considering the phased nature of ISL well development and utilization, and the practice of revegetating disturbed soils after construction, the amount of land that is disturbed by earth-moving activities at any time is relatively small. For example, while the total area disturbed by construction activities between 1987 and 2007 was about 530 ha [1,310 acres] for the Crow Butte ISL facility in Dawes County, Nebraska, only about 50 ha [120 acres] are estimated to be disturbed at any time (Crow Butte Resources, Inc., 2007). After the surface operations are complete and well fields are restored, the final steps of decommissioning and surface reclamation are intended to retum the land to its preoperational conditions.

2.11.2 Spills and Leaks

During ISL operations and aquifer restoration, barren and pregnant uranium-bearing process solutions are moved through pipelines to and from the well field and among different surface facilities (e.g., processing circuit, evaporation ponds). If a pipeline ruptures or fails, process solutions can be released and (1) pond on the surface, (2) run off into surface water bodies, (3) infiltrate and adsorb in overlying soil or rock, or (4) infiltrate and percolate to groundwater. For example, from 2001 to 2005, the operators of the Smith Ranch-Highland uranium ISL facility in Converse County, Wyoming, reported 24 spills of uranium recovery solutions (NRC, 2006). The WDEQ identified more than 80 spills at the Smith-Ranch Highland site during commercial operations from 1988 to 2007 (WDEQ, 2008). This is the largest NRC-licensed ISL uranium recovery facility. The size of the spills at Smith Ranch-Highland has ranged from a 190- to 380-liter [50- to 100-gallon] spill in February 2004 to a 751,400-L [198,500-gal] spill of injection fluid in June 2007 (WDEQ, 2007; NRC, 2006). The spills most commonly involved injection fluids {0.5 to 3.0 mg/l [0.5 to 3.0 parts per million]} uranium, although spills of production fluids {10.0 to 152 mg/l [10.0 to 152 parts per million]} uranium also have occurred (NRC, 2007). These spills have been caused predominantly by the failure of joints, flanges, and unions of pipelines and at wellheads (NRC, 2006, 2007). The large June 2007 spill at Smith Ranch–Highland was the apparent result of a failed fitting. The spilled fluids flowed into a drainage and continued downstream for about 700 m [2,300 ft]. The WDEQ Land Quality Division estimated the affected area at 0.44 ha [1.08 acres] (WDEQ, 2007).

Reporting requirements for spills differ from state to state. NRC requirements for spill reporting are found in Subpart M of 10 CFR Part 20 and at 10 CFR 40.60. Additionally, NRC may incorporate reporting requirements as conditions in operating license. Generally, such NRC and state requirements include an immediate report (e.g., notification within 24 to 48 hours of the spill) followed by a later written report addressing items such as the conditions leading to the spill, the corrective actions taken, and the cleanup results achieved. A licensee documentation of spills helps in final site decommissioning activities.

For hazardous chemicals stored at the processing facility, spill responses would be similar to those described previously for yellowcake transportation, although nonradiological material spills are primarily reportable to the appropriate state agency and EPA. Concrete berms with at least the volume of the tank are used to contain spills from process chemical storage tanks and simplify cleanup (e.g., NRC, 1998a,b). The Occupational Safety and Health Administration sets worker exposure limits to process chemicals at ISL surface facilities. Typical onsite process chemicals and their quantities used at ISL facilities are presented in Tables 2.11-2 and 2.11-3.

Evaporation ponds are typically constructed in accordance with NRC staff guidance (NRC, 2008a), and license conditions require that these ponds be periodically monitored. Pond leaks have, however, occurred at active ISL facilities. For example, at the Crow Butte ISL facility in Dawes County, Nebraska, seven leaks were identified for three commercial evaporation ponds from 1991 through 1997 (NRC, 1998b). The volumes of the leaks ranged from about 257.4 to 1,135.6 L [68 to 300 gal], but in all cases, the leaks involved only the upper liner of the double-lined system. To repair the leaks, the licensee exposed the liner by transferring water to other ponds to lower the water level, patching the holes, and pumping the water from the underdrain system (NRC, 1998b). Since, 1997, the Crow Butte facility has reported and repaired an additional eight pond leaks, with the most recent leak identified and the pond linerrepaired in May 2006 (Teahon, 2006). From 1988 to 1997, one pond leak was reported in 1992 at the Irigary/Christensen Ranch ISL facility in Campbell and Johnson Counties, Wyoming (NRC, 1998a). The licensee corrective actions included temporarily transfering water to expose the liner and repair the leak.

Table 2.11-2. Common Bulk Chemicals Required at the Project Processing Sites*†

Shipped as Dry Bulk Solids	Shipped as Liquids and Gases
Salt (NaCl)	Hydrochloric acid (HCl)
Sodium bicarbonate ($NaHCO_3$)	Sulfuric acid (H_2SO_4)
Sodium carbonate (Na_2CO_3)	Hydrogen peroxide (H_2O_2)
Sodium hydroxide (NaOH)	Oxygen (O_2)
—	Carbon dioxide (CO_2)
—	Anhydrous ammonia (NH_3)
—	Diesel oil
—	Bottled gases
—	Liquefied petroleum gas (LPG)

*NRC. NUREG–1508, "Final Environmental Impact Statement to Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico." Washington, DC: NRC. February 1997.
†Energy Metals Corporation, U.S. "Application for USNRC Source Material License Moore Ranch Uranium Project, Campbell County, Wyoming: Environmental Report." ML072851249. Casper, Wyoming. Energy Metals Corporation, U.S. September 2007.

2.11.3 Groundwater Use

During construction, groundwater use is limited to routine activities such as dust suppression, mixing cements, and drilling support. Although large amounts of groundwater are moved and processed during ISL facility operations, most of the water is reinjected maintaining the overall water balance. A production bleed of about 1–3 percent, means that about 97–99 percent of the water produced from a well field is reinjected for additional uranium recovery. For example, for the proposed Reynolds Ranch addition to the Smith Ranch ISL facility in Converse County, Wyoming, the NRC staff estimated that the amount of water used in the ion-exchange columns at the satellite facilities or discharged to a deep disposal well could be as much as 1,480,000,000 L [391 million gal] over the course of an assumed operating period of 15 years (NRC, 2006). For the Crow Butte ISL facility in Dawes County, Nebraska, the average operating flow rate in 2007 was about 16,200 L/min [4,279 gal/min] (Cameco Resources, Inc., 2008). The total net volume of groundwater produced for 2007 (volume produced–volume injected) was 346,900,000 L [91,640,000 gal], and the production bleed ranged from about 1.1 to 1.6 percent. During the last six months of 2007, about 76,200,000 L [20,130,000 gal] was

disposed in the licensed Class I UIC deep disposal well and about 14,370,000 L [3,800,000 gal] was discharged to the evaporation pond system (Cameco Resources, 2008).

Table 2.11-3. Onsite Quantities of Process Chemicals at *In-Situ* Leach Facilities*

Chemical	Typical Onsite Quantity	Use in Uranium ISL Process
Ammonia (NH_3)	40,820 kg [90,000 lb]	pH adjustment
Sulfuric acid (H_2SO_4)	37,850 L [10,000 gal]	pH control during lixiviant processing, and splitting uranyl carbonate complex into CO_2 gas and uranyl ions in preparation for their precipitation
Liquid and gaseous oxygen	No specific typical quantities available	Oxidant in lixiviant, and precipitation of uranium as an insoluble uranyl peroxide compound
Hydrogen peroxide (H_2O_2)	26,500 L [7,000 gal]	Uranium precipitation and oxidant in lixiviant
Sodium hydroxide (NaOH)	Typically stored in 208-L [55-gal] drums	pH adjustment
Barium chloride ($BaCl_2$)	No specific typical quantities available	Precipitation of radium during groundwater restoration, and wastewater treatment
Carbon dioxide (CO_2)	No specific typical quantities available	Carbonate complexing
Hydrochloric acid (HCl)	37,850 L [10,000 gal]	pH adjustment
Sodium carbonate (Na_2CO_3)	64,350 L [17,000 gal]	Carbonate complexing and resin regeneration
Sodium chloride (NaCl)	127,000 kg [280,000 lb]	Resin regeneration
Hydrogen sulfide (H_2S)	No specific typical quantities available	Groundwater restoration
Sodium sulfide (Na_2S)	No specific typical quantities available	Groundwater restoration

*Mackin, P.C., D. Daruwalla, J. Winterle, M. Smith, and D.A. Pickett. NUREG/CR–6733, "A Baseline Risk-Informed Performance-Based Approach for *In-Situ* Leach Uranium Extraction Licensees." Washington, DC: NRC. September 2001.

2.11.4 Excursions

As discussed in Section 2.4, ISL operations may affect the groundwater quality near the well fields or in overlying or underlying aquifers if lixiviant travels from the production zone and beyond the well field boundaries. Monitoring wells are designed and placed to detect any lixiviant that moves out of the production zone. A monitoring well is placed on excursion status when two or more excursion indicators exceed their respective upper control limits (UCLs)

(NRC, 2003a). Alternate excursion detection procedures (e.g., one excursion indicator exceeded in a monitoring well by a specified percentage) may also be used if approved by NRC. NRC licensees are required by license conditions to identify reporting, monitoring, and response measures to be taken to determine the extent and cause of the excursion, as well as measures to recover the excursion and remove the well from excursion status.

Historical information for several facilities indicates that excursions occur at ISL operations (NRC, 2006, 1998a,b, 1995; Crow Butte Resources, Inc., 2007; Cameco Resources, 2008; Arbogast, 2008). For example, from 1987 to 1998, 49 wells were placed on excursion status at the Irigary and Christensen Ranch uranium recovery facility in Campbell and Johnson Counties in the Wyoming East Uranium Milling Region (NRC, 1998a). Most of these excursions were recovered within a period of weeks to months, but six vertical excursions proved more difficult to return to baseline, with two wells remaining on excursion status for at least 8 years. These excursions were believed to be due to improperly abandoned wells from earlier exploratory programs prior to regulation by a UIC program. In 2007, three wells were on excursion status at the Christensen Ranch project, with only one, originally identified in 2004, remaining on excursion status at the end of 2007 (Arbogast, 2008a). None of the earlier excursions that affected monitoring wells identified in NRC (1998a) were on excursion status in 2007 (Arbogast, 2008b). An additional well at the Christensen Ranch project was placed on excursion status in 2008 (Arbogast, 2008b).

From 1988 through 1995, 22 monitoring wells (11 vertical and 11 horizontal) were placed on excursion status for the Highland Uranium Project located in Converse County in the Wyoming East Uranium Milling Region (NRC, 1995). Most of the excursions were recovered within less than 1 year, but four horizontal excursions lasted up to at least five years. In two of these wells, the excursions were due to a thinning of the confining layer that separated two production zones. Groundwater pumping during restoration of the underlying production zone resulted in a hydraulic gradient that brought excursion fluids down from the overlying aquifer. One of the other excursions was believed to be the result of fluids migrating from an upgradient abandoned uranium mine (NRC, 1995). No cause was identified for the other long-term excursion at the Highland Uranium Project. Only one horizontal excursion was reported between 2001 and 2005 at the Smith Ranch-Highland uranium recovery facility, and corrective action brought the well back below the UCLs within less than one month (NRC, 2006).

At the Crow Butte ISL facility located in Dawes County, Nebraska (Nebraska-South Dakota-Wyoming Uranium Milling Region), the operator reported five vertical excursions into the overlying aquifer from the start of commercial operations in 1989 through the license renewal in 1998 (NRC, 1998b). In two cases, these excursions resulted from well integrity problems (borehole cement contamination and a failed casing coupling). One excursion resulted from a leak in a plugged and abandoned injection well, and the remaining two were believed to result from natural fluctuations in the groundwater quality (NRC, 1998b). Between 1999 and 2006, 17 wells at the Crow Butte facility were placed on excursion status (7 vertical and 10 horizontal) Most of these wells were restored below the UCLs within 1 to 6 months, although one vertical well took almost four years to restore (Crow Butte Resources, Inc., 2007). In the second half of 2007, three horizontal monitoring wells were on excursion status (Cameco Resources, 2008). These excursions were first identified in April 2000, December 2003, and September 2006 (Crow Butte Resources, Inc., 2007). The licensee believes that these longer term excursions resulted from well field geometry and well field flare as a result of ongoing groundwater transfer and well field restoration activities.

Operational experience at these facilities indicates that lixiviant excursions can result from

- Thinning or discontinuous confinement
- Improperly abandoned wells that may provide vertical flow pathways
- Casing failure or other well leaks
- Natural fluctuations in groundwater quality
- Improper balance of well field hydrologic gradients

Most horizontal excursions were recovered quickly (weeks to months) by repairing and reconditioning wells and adjusting pumping rates in the well field, consistent with the findings of Mackin, et al. (2001a). Vertical excursions tended to be more difficult to recover than horizontal excursions, and in a few cases, a well remained on excursion status for as long as 8 years.

2.11.5 Aquifer Restoration

Operational history at NRC-licensed ISL facilities is available to examine aquifer restoration at the well-field scale. Table 2.11-4 shows a summary of restoration data for a 12-ha [30-acre] area covered by Production Units 1–9 at the commercial-scale Cogema Irigaray ISL facility (Cogema, 2006a,b). A comparison of the baseline and postrestoration stability monitoring groundwater analytical data determined that for the water quality in the production zone, the individual restoration and stabilization data fell within the baseline ranges for all constituents except for calcium, magnesium, sodium, carbonate, chlorine, ammonium, total dissolved solids, conductivity, alkalinity, lead, barium, manganese, and radium-226. These data showed that, when comparing premining baseline ranges to postmining stabilization ranges, several constituents did not meet the premining baseline concentration levels. Additionally, postmining mean concentrations for nearly half of the constituents exceeded the premining baseline mean concentrations for the same constituents in Production Units 1–9 (Cogema, 2006a,b).

Catchpole, et al. (1992a,b) provide an early discussion of small-scale restoration efforts for research and development of ISL uranium recovery facilities in Wyoming. These include the Bison Basin facility in Fremont County (described in NRC, 1981), the Reno Creek project in Campbell County, and the Leuenberger Project in Converse County. Restoration activities required treatment of water from nine pore volumes at Bison Basin and five pore volumes at Reno Creek. In all cases, most water quality parameters were returned to within a statistical range of baseline values with the exception of uranium (Bison Basin and Reno Creek) and radium-226 (Leuenberger). For these parameters, Catchpole, et al. (1992a,b) report that water in the well field was returned to the same class of use.

Davis and Curtis (2007) detailed available information on aquifer restoration at ISL uranium recovery facilities. These include a pilot scale study by Rio Algom for the Smith Ranch facility in Converse County, Wyoming (Rio Algom Mining Corporation, 2001); the proposed Crownpoint ISL facility near Crownpoint, New Mexico (NRC, 1997); the commercial-scale A-Well Field at the Highland Uranium Project in Converse County, Wyoming (Power Resources, Inc., 2004a); and the commercial-scale Crow Butte Mine Unit No. 1 in Dawes County, Nebraska (NRC, 2002, 2003c). Rock core laboratory studies that Hydro Resources Inc. conducted for the Crownpoint facility (NRC, 1997a) also provide useful insights to water quality parameters that may present challenges for aquifer restorations.

Table 2.11-4. Irigaray Water Quality Summary for Designated Aquifer Restoration Wells*							
	Mine Units 1–9 Baseline			Mine Units 1–9 Round Four Restoration Results			Samples Exceeding Baseline Range
Constituents	Minimum	Maximum	Mean	Minimum	Maximum	Mean	
Major Ions (mg/L)							
Calcium	1.6	27.1	7.8	11.6	65	28.8	17
Magnesium	0.02	9	0.9	2.8	13	7.0	7
Sodium	95	248	125	107	275	185.6	2
Potassium	0.92	17.5	2.4	1.1	4.9	2.9	0
Carbonate	0	98	13.2	<1.0	<1.0	0.8	0
Bicarbonate	5	144	88.3	5.1	631	409	31
Sulfate	136	504	188.1	62.8	237	132.0	0
Chloride	5.3	15.1	11.3	0.1	117	39.4	32
Ammonia	0.05	1.88	0.3	0.05	36.1	8.5	13
Nitrogen Dioxide	<0.1	1	<0.4	<0.1	<0.1	<0.1	0
Nitrate	0.2	1	0.9	<0.1	0.12	0.1	0
Fluoride	0.11	0.68	0.29	0.1	0.22	0.12	0
Silica Dioxide	3.2	17.2	8.3	2.5	7.3	4.99	0
Total Dissolved Solids	308	784	404	343	968	626	5
Specific Conductivity	535	1,343	658	604	1,970	1094	5
Alkalinity	67.8	232	104	127	518	345	30
pH	6.6	11.0	9.00	7.07	8.40	7.76	0
Trace Metals (mg/L)							
Aluminum	0.05	4.25	0.160	<0.1	0.140	0.102	0
Arsenic	<0.001	0.105	0.007	<0.001	0.029	0.005	0
Barium	<0.01	0.12	0.060	0.03	0.200	0.095	1
Boron	<0.01	0.225	0.110	<0.05	0.100	0.088	0
Cadmium	<0.002	0.013	0.005	<0.002	0.005	0.004	0
Chromium	<0.002	0.063	0.020	<0.005	0.050	0.039	0
Copper	<0.002	0.04	0.011	<0.01	0.020	0.010	0
Iron	0.019	11.8	0.477	<0.03	0.500	0.113	0
Lead	<0.002	0.05	0.020	<0.001	0.090	0.039	1
Manganese	<0.005	0.19	0.014	0.060	0.950	0.215	13
Mercury	<0.0002	0.001	0.0004	<0.0002	<0.001	<0.001	0
Molybdenum	<0.02	0.1	0.060	<0.01	<0.1	0.069	0
Nickel	<0.01	0.2	0.100	<0.05	<0.05	<0.05	0
Selenium	<0.001	0.416	0.013	<0.001	0.086	0.019	0
Vanadium	<0.05	0.55	0.070	<0.05	<0.1	0.088	0
Zinc	0.009	0.07	0.016	<0.01	<0.01	<0.01	0
Radiometric (pCi/L)							
Uranium	0.0003	18.60	0.52	0.08	6.03	1.83	0
Radium-226	0	247.7	39.6	23.50	521.0	130.7	3

*Wichers, D.L. "Re: Request: Summary Table Irigaray Mine Unit Restoration RAI Response." E-mail to R. Linton (August 11), NRC. Mills, Wyoming: Cogema Mining, Inc. 2006.

Davis and Curtis (2007) generally concluded that for the sites and data they examined, aquifer restoration took longer and required more pore volumes than originally planned. For example, at the A-Well Field at the Highland Uranium Project, the licensee's original plan anticipated that restoration would last from four to seven years and require treating 5–7 pore volumes of groundwater. When uranium recovery in the well field ended in 1991, the baseline and class of use were not restored in the well field until 2004 (Table 2.11-5), and more than 15 pore volumes of water were involved (NRC, 2006, 2004). Similarly, WDEQ has noted that the C-Well field at the Smith Ranch-Highland Uranium Project has been undergoing restoration for 10 years (WDEQ, 2008). At the Crow Butte Mine Unit No. 1, more than 9.85 pore volumes of

Table 2.11-5. Baseline Groundwater Conditions, Aquifer Restoration Goals, and Actual Final Restoration Values the U.S. Nuclear Regulatory Commission Approved for the Q-Sand Pilot Well Field, Smith Ranch, Wyoming*†

Parameter (units)	Range	Mean	Restoration Goal	Actual Restoration
Arsenic (mg/L) ‡	0.001–.0013	0.004	0.05	0.008
Boron (mg/L)	0.002–0.70	0.15	0.54	0.14
Calcium (mg/L)	24–171	72	120	78
Iron (mg/L)	0.01–0.27	0.025	0.3	0.24
Magnesium (mg/L)	3–22	16	0.092	0.06
Manganese (mg/L)	0.01–0.077	0.023	Not applicable	0.1
Selenium (mg/L)	0.001–0.024	0.004	0.029	0.003
Uranium (mg/L)	0.001–3.1	0.28	3.7	1.45
Chloride (mg/L)	4–65	18	250	15
Bicarbonate (HCO_3) (mg/L)	129–245	199	294	254
Carbonate (CO_3) (mg/L)	Nondetectible–75	18	15	Nondetectible
Nitrate (mg/L)	0.1–1.0	0.4	Not applicable	0.13
Potassium (mg/L)	7–34	12	23	8
Sodium (mg/L)	19–87	28	41	38
Sulfate (mg/L)	100–200	124	250	128
Total dissolved solids (mg/L)	155–673	388	571	443
Specific conductivity (μmhos/cm)	518–689	582	827	642
pH (standard units)	7.5–9.4	8.0	6.5–8.6	7.0
Radium-226 (pCi/l)	6–1132	340	923	477
Thorium-230 (pCi/l)	0.027–4.65	1.03	5.62	3.4

*NRC. "Environmental Assessment for the Addition of the Reynolds Ranch Mining Area to Power Resources, Inc.'s Smith Ranch/Highlands Uranium Project Converse County, Wyoming." Source Material License No. SUA–1548. Docket No. 40-8964. Washington, DC: NRC. 2006.
†Sequoyah Fuels Corporation. "Re: License Application, Smith Ranch Project, Converse County, Wyoming." ML8805160068. Glenrock, Wyoming: Sequoyah Fuels Corporation. 1988.
‡1 mg/L = 1 ppm

groundwater were used in all the stages of aquifer restoration over approximately 5 years as compared to the 8 pore volumes estimated before restoration (NRC, 2002, 2003c). Crow Butte Resources extracted uranium from an additional 26 pore volumes using ion exchange, without lixiviant injection, prior to active restoration.

As a field test of groundwater stabilization during aquifer restoration, hydrogen sulfide gas was injected as a reductant into the Ruth ISL research and development facility in Campbell County, Wyoming. After 6 weeks of hydrogen sulfide injection, pH dropped relatively quickly from 8.6 to 6.3, and sulfate concentration increased from 28 ppm to 91 ppm indicating a more reducing environment (Schmidt, 1989; Davis and Curtis, 2007). Concentrations of dissolved uranium, selenium, arsenic, and vanadium decreased by at least one order of magnitude. After 1 year of monitoring, however, reducing conditions were not maintained, and uranium, arsenic, and radium concentrations began to increase.

Based on the available field data from aquifer restoration, Davis and Curtis (2007) concluded that aquifer restoration is complex and results could be influenced by a number of site-specific hydrological and geochemical characteristics, such as preoperational baseline water quality, lixiviant chemistry, aquitard thickness and continuity, aquifer mineralogy, porosity, and permeability. In some cases, such as at Bison Basin and Reno Creek, the aquifer was restored in a relatively short time. In other cases, restoration required much more time and treatment than was initially estimated (e.g., the A- and C- Well Fields at the Highland ISL facility.

2.11.6 Socioeconomic Information

Because they are generally located in remote areas, uranium ISL facilities tend to be important employers in the local economy. The total number of full-time, permanent employees and local contractors varies during an operational life that may span several decades. Based on employment levels at existing operations and projected employment for proposed projects, staff levels at ISL facilities range from about 20 to 200, with peak employment depending on the scheduling of construction, drilling, and operational activities (Crow Butte Resources, Inc., 2007; Power Resources, Inc., 2004a; NRC, 1997a).

Another economic effect from ISL facilities is contributions to the local economy through purchases and through tax revenues from the uranium produced at the facility. For example, at the Crow Butte ISL facility in Dawes County, Nebraska, local purchases of goods and services in 2006 were estimated at about $5,000,000 (Crow Butte Resources, Inc., 2007). Annual tax revenues depend on uranium prices and the amount of uranium produced at a given facility. For example, for a 272,155-kg [600,000-lb] increase in annual yellowcake production at the Crow Butte facility at a price of $80/lb, an incremental contribution to federal, state, and local taxes on the order of $1 million to $1.4 million would result (Crow Butte Resources, Inc., 2007).

2.12 Alternatives Considered and Included in the Impact Analysis

The NRC's environmental review regulations in 10 CFR Part 51 that implement the National Environmental Policy Act (NEPA) require the NRC to consider reasonable alternatives, including the no-action alternative, to a proposed action before acting on a proposal. The intent of this requirement is to enable the agency to consider the relative environmental consequences of an action given the environmental consequences of other activities that also meet the need for the action, as well as the environmental consequence of taking no action at all. The information in

this section does not constitute NRC's final consideration of reasonable altematives for the site-specific environmental reviews of ISL license applications.

2.12.1 The No-Action Alternative

As defined in Chapter 1, the proposed federal action is NRC's determination to grant an application to obtain, renew, or amend a source material license for an ISL facility. Under the no-action alternative, NRC would deny the applicant's or licensee's request. As a result, the new license applicant may choose to resubmit the application to use an altemate uranium recovery method or decide to obtain the yellowcake from other sources. Licensees whose renewal application is denied would have to commence shutting down operations in a timely manner. Denials of license amendments would require the licensee to continue operating under its previously approved license conditions.

2.13 Alternatives Considered and Excluded From the Impact Analysis

Alternative methods for uranium recovery include conventional mining/milling methods and heap leaching. Heap leaching (i.e., use of chemical solutions to leach uranium from a pile of crushed ore) may be used for low grade or small ore bodies, but mining and some crushing and grading is necessary to build up the ore pile (EPA, 2007a; NRC, 1980). The heap leach process is a technology that is considered to be part of the conventional mining and milling industry; NRC regulates this technology using the criteria in 10 CFR 40, Appendix A, that are deemed applicable to such operations (NRC, 1980, Appendix B). These two altemative uranium recovery technologies are discussed further in Appendix C.

Because the GEIS focuses on the future licensing of ISL facilities and does not evaluate available technologies for uranium recovery, conventional mining/milling and heap leaching were not included in the impact analysis. However, such uranium recovery methods may be among the reasonable alternatives evaluated in a site-specific review of an ISL license application. As described in Section 2.1, there are particular types of uranium deposits that are amenable to ISL uranium recovery technology. In certain cases (e.g., the ore body is located near the surface, higher grade ores are present, the ore deposit is in an unsaturated formation), these deposits may also be accessible by conventional mining techniques, with the uranium in the mined ore recovered by conventional milling methods or by heap leaching. Therefore, a reasonable range of alternatives to be considered will be addressed in the site-specific environmental reviews.

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