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NUREG-XXXX

Preliminary Draft Final Environmental Impact Statement

The Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico, Proposed by Hydro Resources Inc.

Docket No.
License No.

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

November 1996

NL17

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Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

ABSTRACT

This Final Environmental Impact Statement (FEIS) addresses the proposed action of issuing a combined source and byproduct material license and minerals operating leases for federal and Indian lands to Hydro Resources, Inc. (HRI). This action would authorize HRI to conduct in-situ leach (ISL) uranium mining in McKinley County, New Mexico. Such mining would involve drilling wells to the ore bodies, then recirculating groundwater with added oxygen to mobilize uranium found in the rock. Uranium would then be removed from the solution using ion exchange technology in processing plants located at three separate sites. As proposed by HRI, a central plant would provide drying and packaging equipment for the entire project.

The Draft Environmental Impact Statement (DEIS) for the proposed action was prepared by an interagency review group, including the Nuclear Regulatory Commission (NRC), the Bureau of Indian Affairs (BIA), and the Bureau of Land Management (BLM), and published in October 1994. After weighing the environmental, technical, and other benefits of the proposed action against environmental and other costs, the reviewing agencies concluded that the appropriate action was to issue the requested license and proposed leases authorizing HRI to proceed with the project as discussed in the DEIS. This FEIS re-evaluates the proposed licensing action on the basis of written and oral comments received on the DEIS and on additional information obtained in 1995 and 1996. The FEIS describes and evaluates (1) the purpose and need for the proposed action, (2) alternatives to the proposed action, (3) the environmental resources that could be affected by the proposed action and alternatives, (4) the potential environmental consequences of the proposed action and alternatives, and (5) the economic costs and benefits associated with the proposed action and alternatives. Based on this environmental and economic assessment, the FEIS makes recommendations concerning the requested license and proposed leases.

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SUMMARY AND CONCLUSIONS

This FEIS addresses the pr sed action of issuing Hydro Resources, Inc. (HRI) a combined source and byproduct material license from the Nuclear Regulatory Commission (NRC) and minerals operating leases for federal and Indian lands from the Bureau of Land Management (BLM) and the Bureau of Indian Affairs (BIA). The license and leases would allow HRI to conduct in-situ leach (ISL) uranium mining, also known as solution mining, in McKinley County, New Mexico. By issuing the license and leases, NRC, BLM, and BIA would retain programmatic and regulatory oversight in administrative matters and would impose operating restrictions and specify monitoring, recordkeeping, and reporting requirements as conditions of the license and leases.

As summarized below, this FEIS describes the evaluation conducted concerning (1) the purpose and need for the proposed action, (2) alternatives to the proposed action, (3) the environmental resources that could be affected by the proposed action and alternatives, (4) the potential environmental consequences of the proposed action and alternatives, and (5) the economic costs and benefits associated with the proposed action and alternatives. The evaluation is based on a comprehensive review of HRI's environmental reports, related submittals, independent information sources, and written and oral comments on the DEIS.

On April 25, 1988, HRI submitted an application to the NRC proposing to construct and operate ISL facilities at its Church Rock site in McKinley County, New Mexico. HRI subsequently amended its proposal to address additional lease areas near Crownpoint, New Mexico, and to propose that central processing be conducted in a plant located in Crownpoint. The combined projects are designed to extract a total of 32 million kg (70 million pounds) of uranium reserves, at a maximum rate of approximately 1.5 million kg/yr (3 million pounds per year).

The lease areas proposed by HRI comprise nearly 1040 has (2600 acres) known as the Church Rock, Unit 1, and Crownpoint sites. Each area is located in McKinley County, northeast of Gallup, New Mexico.

HRI proposes to construct well fields in areas of its claims and minerals operating leases selected for their economic ore reserves. Existing and new surface facilities at each site would be used as processing plants for extracting uranium from aqueous mining solutions. Groundwater in the Westwater Canyon Member of the Morrison Formation would be fortified with dissolved oxygen and sodium bicarbonate, then continuously recirculated to oxidize and mobilize uranium minerals. The process would use a complex pattern of injection and recovery wells drilled into the ore zone. Each production well would be pumped at about 95 liters per minute (lpm) [25 gallons per minute (gpm)], and enough patterns would operate in each wellfield area to provide a maximum processing plant flow rate of 15,000 lpm (4000 gpm).

Uranium would be recovered from the mining solution in each processing plant by circulating it through ion exchange (IX) columns. IX columns would be alternately taken off line, and the uranium stripped, precipitated, and concentrated. All uranium slurry produced would be dried using a single dryer located in the central processing plant at Crownpoint. Uranium slurry would be transported by truck from the satellite Church Rock and Unit 1 facilities to Crownpoint for further drying. The Crownpoint processing plant would use an existing building constructed for earlier uranium mining. New satellite processing plants would be constructed at Church Rock and Unit 1. Approximately 2.5 has (6 acres) of land would be

cleared to construct each satellite plant, including buildings, storage and parking areas, and waste water retention ponds.

HRI proposes to restore groundwater quality by sweeping the ore zone with outlying clean groundwater and flushing the ore zone by recirculating injected decontaminated water. Restoration criteria would be established on a parameter-by-parameter basis, and the primary goal of restoration would be to return all parameters to baseline conditions. Individual parameters that cannot be returned to baseline by reasonable efforts, on a mine-unit average basis, would be returned at least to concentration levels corresponding to the greatest potential pre-mining use of the groundwater, based on the State of New Mexico drinking water and livestock standards.

HRI proposes to minimize waste water by employing a two-stage treatment system for all liquid effluents. Treated water that meets groundwater standards would be recirculated in the aquifer during restoration, or injected back into the Westwater Canyon sandstone in a location isolated from mine units. Alternatively, excess treated waste water that cannot be disposed of in this manner would be applied to the land using ordinary irrigation equipment. The proposed effluent management program differs from the approach used at similar facilities that typically discharge all of their liquid effluents using either land application or evaporation ponds. Most solid wastes that would be generated by the mining process are defined as byproduct material in the Atomic Energy Act of 1954, and would require disposal at a licensed disposal site elsewhere.

After HRI concludes the mining operation and demonstrates complete aquifer restoration, wells would be plugged and abandoned; processing facilities would be decontaminated or decommissioned; all contaminated materials would be removed to a licensed waste disposal site; and all disturbed areas would be surveyed, decontaminated to acceptable levels, recontoured, revegetated, and released for unrestricted use.

Including the proposed action, this FEIS evaluates three alternatives. Under Alternative 1 (the proposed action), NRC would issue HRI a license for the construction and operation of facilities for ISL uranium mining and processing at the Church Rock, Unit 1, and Crownpoint sites. HRI would conduct its operations as described in its submittals with no significant changes resulting from regulatory review. Under Alternative 2 (modified action), NRC would issue HRI a license for the construction and operation of facilities for ISL uranium mining and processing at alternative sites and/or using alternative liquid waste disposal methods. Under Alternative 3 (no action), NRC would not issue HRI a license for the construction and operation of facilities for ISL uranium mining and processing at the Church Rock, Unit 1, or Crownpoint sites.

This FEIS evaluates the potential environmental impacts and economic costs and benefits of the proposed action, modified action, and no action. The evaluation is based on the requirements of the National Environmental Policy Act (NEPA) of 1969, NRC's "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions" (10 CFR 51), and BLM's "Surface Exploration, Mining, and Reclamation of Lands" (25 CFR 216) and "Solid Minerals Exploration and Mining Operations" (43 CFR 3590). On the basis of this independent review, staff concludes that HRI should be issued a combined source and material byproduct license from NRC and minerals operating leases from BLM and BIA. However, the license and leases should be conditioned on the various mitigation measures recommended in Section 4 of this FEIS that are intended to protect public health and safety and the environment.

ACRONYMS AND ABBREVIATIONS

AIRFA	American Indian Religious Freedom Act
ALARA	As Low As Reasonably Achievable
ASTM	American Society for Testing and Materials
ASME	American Society of Metallurgical Engineers
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
DEIS	Draft Environmental Impact Statement
EIS	Environmental Impact Statement
ER	Environmental Report
EPA	U.S. Environmental Protection Agency
HDPE	high-density polyethylene
HRI	Hydro Resources, Inc.
ISL	in-situ leach
IX	ion exchange
MSHA	U.S. Mine Safety and Health Administration
NCRP	National Council of Radiation Protection
NEPA	National Environmental Policy Act
NMED	State of New Mexico Environmental Department
NPDES	National Pollution Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NTUA	Navajo Tribal Utility Authority
NWS	National Weather Service
PVC	polyvinyl chloride
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
R#W	Range # West
SCS	U.S. Soil Conservation Service
TDS	Total Dissolved Solids
TEDE	Total Effective Dose Equivalent
TVA	Tennessee Valley Authority
T#N	Township # North
UCL	Upper Control Limit
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
WQA	New Mexico Water Quality Act

UNITS OF MEASURE AND METRIC CONVERSIONS

acre	43,560 square feet
acre-foot	43,560 cubic feet; 325,829 gallons; 1.2 million liters
Bq/g	μCi/g × 37,000; pCi/g × 3.7E-2
centimeter	0.39 inches
cubic foot	7.48 gallons; 28.3 liters
cubic meter	35.3 cubic feet
C/kg (coulomb)	2.58E-4 roentgen
	2.58E-10 μR
hectare (ha)	10,000 square meters; 2.47 acres
kilogram	2.20 pounds
kilometer	0.62 miles
MBq	Ci × 37,000
	pCi × 3.7E-8
meter	3.28 feet
millisievert	100 mrem
pCi/l	E-9 μCi/ml
pCi/g	E-6 μCi/g
Sievert	100 rem

ACKNOWLEDGMENTS

This Final Environmental Impact Statement was prepared through a joint effort led by the Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. Significant contributions were prepared by the Bureau of Land Management, Albuquerque District Office, and the Bureau of Indian Affairs, Navajo Area Office, Gallup, New Mexico. While preparing the report, the reviewing agencies relied heavily upon the Environmental Reports and related information submitted by the applicant, Hydro Resources, Inc., of Dallas, Texas. The review also benefitted from the inputs of the New Mexico Environmental Department, as well as numerous agencies of the Navajo Nation.

1. PURPOSE AND NEED FOR THE PROPOSED ACTION

1.1 INTRODUCTION

Under the Atomic Energy Act of 1954, as amended, the Nuclear Regulatory Commission (NRC) has statutory responsibility for the protection of public health and safety and the environment related to source and byproduct nuclear material (defined as uranium and/or thorium in any form, or ores containing 0.05 percent or more by weight of uranium and/or thorium). One portion of NRC's responsibility is to issue source material licenses to "receive title to, or to receive, possess, use, transfer, or deliver any source material after removal from its place of deposit in nature" (10 CFR 40).

On April 25, 1988, Hydro Resources, Inc., (HRI) submitted an application to the NRC for a source material license to commercially produce uranium using in-situ leach (ISL) mining (also known as solution mining) at its Church Rock property in McKinley County, New Mexico (Figure 1.1). HRI had already initiated its application in accordance with 10 CFR 51.45 by submitting an environmental report (ER) to the NRC on April 13, 1988. On May 8, 1989, HRI submitted a supplemental ER and amended its application to include uranium recovery processing at an existing mine facility in Crownpoint, New Mexico (Figure 1.1). On April 23, 1992, HRI submitted a second supplemental ER and amended its application to include ISL mining on allotted lands known as Unit 1 west of the existing facility at Crownpoint (Figure 1.1). On July 31, 1992, HRI submitted a third supplemental ER and amended its application to include ISL mining on lands associated with the existing facility in Crownpoint (Figure 1.1). HRI's proposal to conduct ISL mining and processing at the Church Rock, Unit 1, and Crownpoint sites is referred to collectively as the Crownpoint Uranium Solution Mining Project.

Pursuant to 10 CFR 51, NRC's regulations for implementing the National Environmental Policy Act of 1969 (Public Law 91-190) (NEPA), the NRC published the *Draft Environmental Impact Statement to Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico* (NUREG-1508) in October 1994. The draft environmental impact statement (DEIS) was prepared by an interagency review group consisting of the NRC and two federal cooperating agencies, the Bureau of Land Management (BLM) and the Bureau of Indian Affairs (BIA).

1.2 DESCRIPTION OF THE PROPOSED ACTION

The proposed action by the NRC is to issue HRI a source material license for the construction and operation of facilities for ISL uranium mining and processing at the Church Rock, Unit 1, and Crownpoint sites. The proposed action by the BLM and BIA is to grant HRI minerals operating rights and leases on certain federal and Indian lands on which the proposed project would be located.

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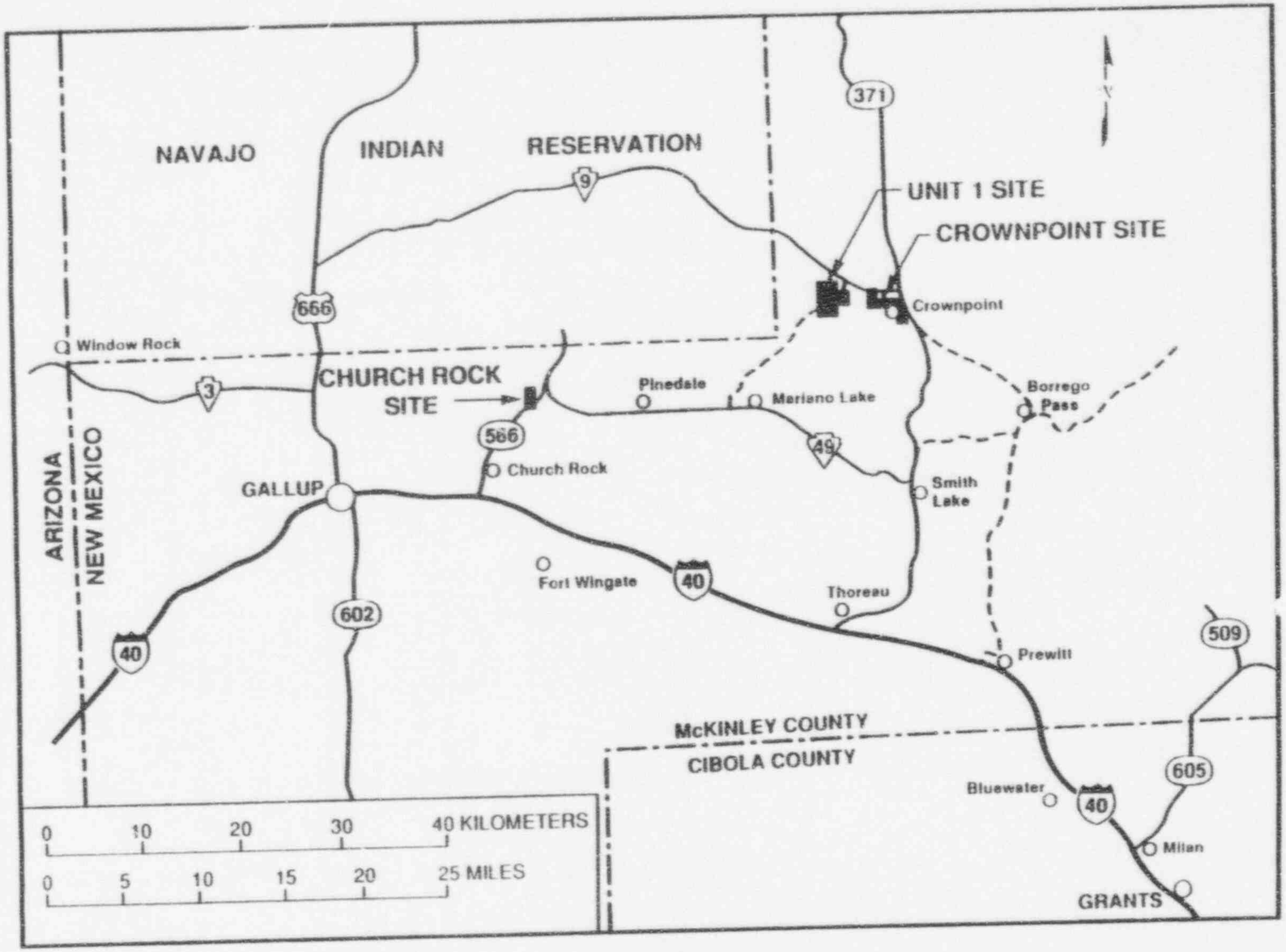

Figure 1.1. Regional index map of west-central New Mexico and the project site locations.

1.3 PURPOSE AND NEED FOR THE PROPOSED ACTION

The purpose of the proposed action is to regulate HRI's proposal to construct and operate facilities for ISL uranium mining and processing. The NRC's need for action is to fulfill its statutory responsibility to protect public health and safety and the environment related to source nuclear material (Atomic Energy Act of 1954, as amended). The BLM and BIA's need for action is to fulfill their statutory responsibilities to regulate mining activities on federal and Indian lands (Mining Law of 1872; Allotted Lands Mineral Leasing Act of 1909; Mineral Leasing Act of 1920; National Historic Preservation Act of 1966; Endangered Species Act of 1973; Federal Land Policy and Management Act of 1976).

1.4 SCOPE OF THE EIS

Under NEPA, all federal agencies must consider the effects of their actions on the environment. Section 102(1) of NEPA requires that the policies, regulations, and public laws of the United States be interpreted and administered in accordance with the policies set forth in the Act. It is the intent of NEPA to have federal agencies incorporate consideration of environmental issues into their decision-making processes.

NRC's regulations for implementing NEPA are contained in 10 CFR 51. To fulfill its responsibilities under NEPA, NRC published the *Draft Environmental Impact Statement to Construct and Operate the Crownpoint Uranium Solution Mining Project, Crownpoint, New Mexico* and conducted public hearings on the DEIS. This FEIS analyzes the environmental impacts and economic costs of the proposed action and of alternatives to the proposed action and incorporates revisions in response to public and agency comments on the DEIS. Appendix A of this FEIS contains responses to the public and agency comments. The FEIS addresses potential impacts to the following resources: air quality; geology and soils; hydrology (including groundwater and surface water); ecology; land use; socioeconomics; aesthetics; cultural resources; and environmental justice. The FEIS also evaluates transportation risk and health physics and radiological impacts and contains cost/benefit analyses for the proposed action and alternatives.

1.5 SCOPING PROCESS

The NRC, BLM, and BIA initiated a scoping process to identify significant issues to be addressed in the DEIS in 1992. The BIA, representing the three agencies, issued a Notice of Intent (NOI) to prepare the DEIS in the Federal Register (57 FR 39326) on August 28, 1992. Two public scoping meetings were held on September 24, 1992, in Window Rock, Arizona, and Crownpoint, New Mexico. At these meetings, NRC, BLM, and BIA described their review procedures and responsibilities, and HRI representatives described the proposed project. State, local, and tribal government agency representatives and concerned local citizens also made statements and asked questions at the meetings.

The NRC received one letter commenting on the scope of the DEIS. The NRC, BLM, and BIA considered the oral and written comments in determining the scope of the DEIS. The issues raised during scoping process were described in Appendix A of the DEIS.

The NRC conducted three public hearings to solicit oral and written comments on the DEIS. Two public hearings were held in Crownpoint, New Mexico, on February 22, 1995, and one was held in Church Rock, New Mexico, on February 23, 1995. A total of 76 participants provided oral comments at the meetings, and the NRC received 52 sets of written comments. Responses to written comments are provided in Appendix A of this FEIS, and revisions in response to both oral and written comments have been incorporated in the FEIS text as appropriate.

NRC staff has met federal requirements for providing information and making the DEIS available, and in some cases exceeded the requirements by providing additional copies of the DEIS and translators at all meetings. Nevertheless, NRC staff understands that some individuals had difficulty obtaining a copy of the DEIS. NRC also acknowledges that the technical information contained in the DEIS is difficult to understand, especially for native speakers of languages other than English, and that language barriers may have prevented some people from becoming informed about the proposed action and from commenting on the DEIS. Nevertheless, many people did comment and those comments are addressed in Appendix A and reflected in revisions made throughout this FEIS. In the context of environmental justice, particularly the U.S. Presidential executive order and NRC guidelines, and because so many people have shown their interest in the EIS process, additional reasonable efforts to facilitate communication between the public and NRC are being made. These efforts include wider distribution of this FEIS, and, to improve the understanding of the local people, translating the summary section of the FEIS into Navajo. Copies of the translation are available through the NRC Public Document Room, 2120 L Street, N.W., Lower Level, Washington, D.C. 20402-9328.

1.6 COOPERATING AGENCIES

In addition to the BLM and BIA serving as federal cooperating agencies in this NEPA process, the State of New Mexico Environmental Department (NMED) is serving as a state cooperating agency. NMED's authority for conducting underground injection control (UIC) programs in compliance with 40 CFR 146, "Underground Injection Control Program: Criteria and Standards," stems from a primacy agreement between the State of New Mexico and the U.S. Environmental Protection Agency (EPA). NMED's authority does not extend to Unit 1 allotted lands, where EPA retains authority for UIC permitting.

To conduct the proposed ISL mining operations, HRI must obtain from the State a "Temporary Aquifer Designation" requiring that groundwater quality be restored to background conditions after mining is completed. In addit[illegible]ate would require HRI to implement mechanical integrity test procedures for all wells, to obtain s[illegible]s for groundwater restoration, and to plug and abandon wells used in the mining project.

The New Mexico Water Quality Act (WQA) provides the basis for State regulations that require all persons proposing to discharge effluent on or into the ground to submit a proposal for review to determine if a discharge permit is necessary. This review is conducted independently of the federal NEPA process.

For the Crownpoint project, the NMED is conducting a parallel technical review addressing HRI's need for permits and temporary exemptions from groundwater protection standards in each lease area. Specifically, the NMED is reviewing HRI's application for discharge plan No. DP-870 for ISL mining at Crownpoint, and proposed modifications to an existing discharge plan, No. DP-558, for ISL operations at Church Rock.

HRI's discharge plan applications address measures to ensure that discharged effluent would not contaminate any existing Underground Source of Drinking Water (USDW) of less than 10,000 milligrams per liter (mg/L) total dissolved solids, now or in the foreseeable future. The applications must also include commitments for contingency plans in case the facility fails to operate as designed, and a closure plan that would remove and/or neutralize any materials that could produce leachate after the facility ceases to operate.

2. ALTERNATIVES INCLUDING THE PROPOSED ACTION

This FEIS evaluates three alternatives:

- Alternative 1 (the proposed action): issue HRI a license for the construction and operation of facilities for ISL uranium mining and processing at the Church Rock, Unit 1, and Crownpoint sites;
- Alternative 2 (modified action): issue HRI a license for the construction and operation of facilities for ISL uranium mining and processing at alternative sites and/or using alternative liquid waste disposal methods; and
- Alternative 3 (no action): do not issue HRI a license for the construction and operation of facilities for ISL uranium mining and processing at the Church Rock, Unit 1, or Crownpoint sites.

These alternatives are described in detail in Sections 2.1, 2.2, and 2.3.

This FEIS does not evaluate alternative uranium mining methods. The DEIS determined that surface and open pit mining are not reasonable alternatives because the ore bodies at the proposed sites are too deep to be extracted economically (BLM 1986). Further, underground mining was found to have more significant environmental impacts than ISL mining, and the ore from underground mining would require processing at a conventional uranium mill to produce the final product. Significant quantities of tailings (residual rock materials after uranium removal) would be produced by conventional milling, which are normally disposed of onsite at the conclusion of the mill's operating life. NUREG-0706 *Final Generic Environmental Impact Statement on Uranium Milling* (NRC 1980a) provides a detailed evaluation of impacts associated with tailings disposal from conventional uranium milling. The cumulative environmental impacts of underground mining and conventional milling would be more severe than those of ISL mining. Consequently, underground mining and conventional milling are not evaluated in this FEIS.

2.1 ALTERNATIVE 1 (THE PROPOSED ACTION)

The action proposed by the NRC is to issue HRI a license to construct and operate facilities for ISL uranium mining and processing at the Church Rock, Unit 1, and Crownpoint sites (Figure 1.1). Under HRI's proposal, the Church Rock and Unit 1 facilities would operate as satellite processing facilities, producing precipitated uranium slurry (also known as yellowcake slurry) for shipment by truck to the Crownpoint site. The Crownpoint facility would operate as the central processing facility for the project, producing yellowcake slurry as well as drying and packaging the slurry from all three sites for final shipment. This section provides a summary of HRI's proposed project, including descriptions of the ISL process and facilities that would be used and the sites that would be developed.

2.1.1 Description of the Proposed ISL Process and Facilities

The ISL uranium recovery process proposed by HRI involves two primary operations. The first occurs in the well fields, where barren mining solution (a mixture of groundwater, oxygen, and bicarbonate known as lixiviant) would be injected through wells into an ore zone, and pregnant lixiviant (lixiviant that contains

uranium ore) would be withdrawn from production wells. The second operation occurs at the processing plants, where uranium would be extracted from the pregnant lixiviant.

2.1.1.1 Well Field Procedures and Equipment

Injection and production wells used for ISL mining would be drilled and constructed using standard mud-rotary drilling techniques for deep water wells. In each well field, injection wells would be arranged near production wells as couplets or geometric patterns designed for optimal uranium recovery. Typical well fields exhibit a repeating five- or seven-spot pattern, where each production well is surrounded by four or six injection wells (Figure 2.1). HRI would consider the geometry of the ore body and surface topography to determine the appropriate well field patterns.

Designing, constructing, testing, and operating injection wells would primarily be subjected to regulation through the UIC program conducted by the U.S. Environmental Protection Agency (EPA) and the State of New Mexico. The proposed program would require authorization from EPA and the State to use Class III injection wells. HRI's proposed methods and materials to construct injection, production, and monitoring wells are in general accordance with EPA requirements for Class III injection wells found in 40 CFR 146. The design and configuration of all wells would be the same to ensure that each complies with requirements for injection.

HRI proposes that injection and production well casings be constructed from a combination of threaded fiberglass and solvent-welded polyvinyl chloride (PVC). Fiberglass casing would be required in wells where differential drawdown would exceed 120 m (400 ft). PVC may be used in other applications. HRI's proposed casing specifications are listed in Table 2.1.

Table 2.1. HRI's design specifications for well casings

	Injection/production wells	Monitor wells
Casing	Fiberglass	PVC
Operating temperature	150°F maximum	120°F maximum
Operating pressure	1000 psi	250 psi
Ultimate collapse pressure	1000 psi	350 psi
Cement volume	At least 1.1 of annulus volume	Same
Screen	Perforated fiberglass or PVC screen	PVC screen

Casings in injection, production, and monitoring wells would require centering stabilizers to maintain the casing in the center of the hole. Each well would be properly sealed against the rock formations by backfilling the annular space using an approved cement grout with a bentonite gel additive. Cement would be forced into the annulus from the bottom, and would be returned to the surface to ensure a complete seal.

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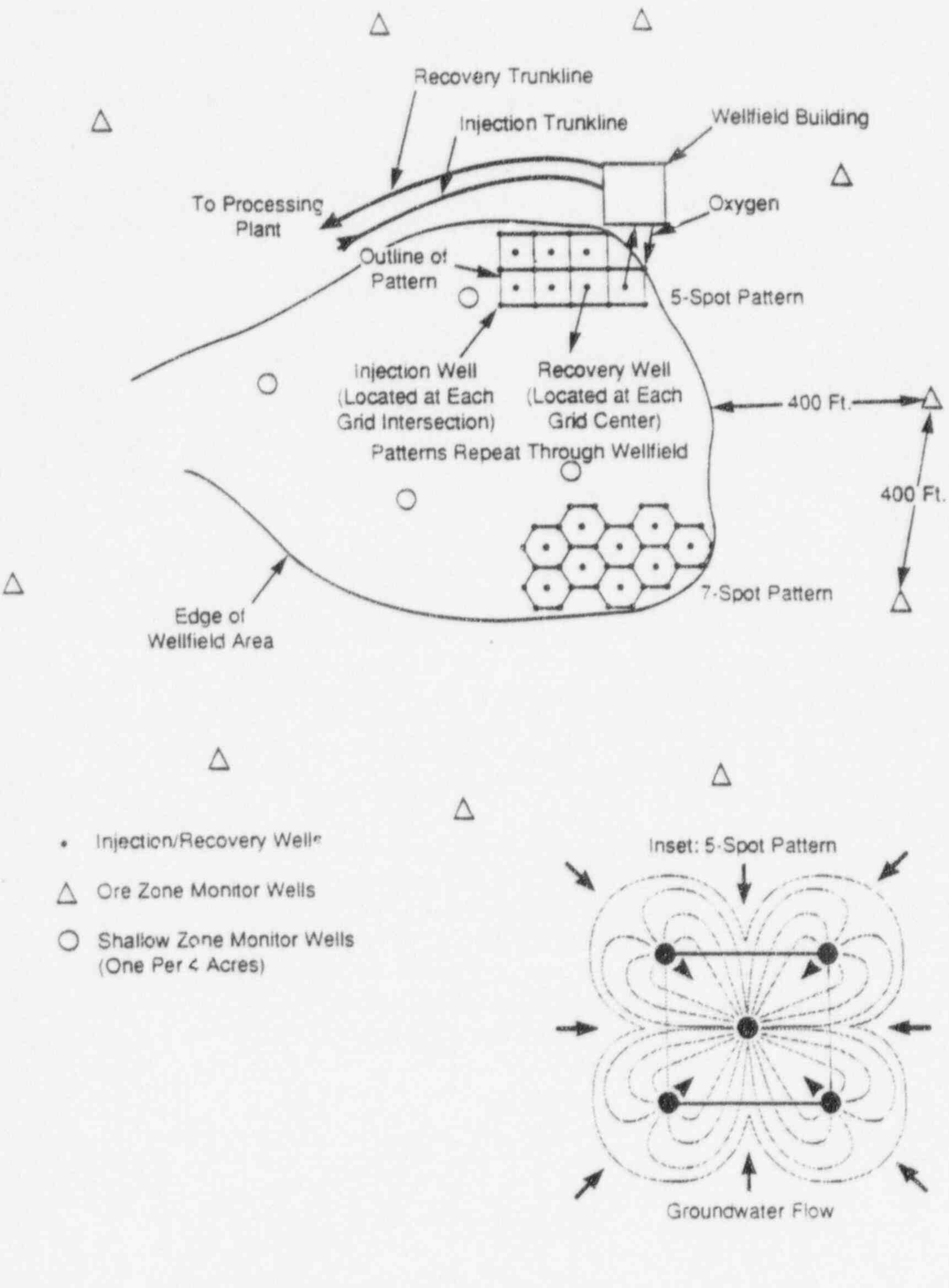

Figure 2.1. Schematic diagram of a well field showing injection/production well patterns, monitor wells, manifold building, and pipelines.

HRI proposes to open each well by installing integral screens with casing, by under-reaming the casing and installing a telescoped screen, or by using perforated fiberglass casing (Figure 2.2).

Each well would be tested for mechanical integrity before use. The purpose of the test is ensure that each well prevents hydraulic communication from one aquifer to another. The test is designed to detect imperfections in the casing sections, inadvertent damage from under-reaming, connections between sections, and the cement grout sealing the casing in place. HRI's proposed test consists of pressurizing the casing and monitoring it for pressure loss. Additionally, HRI's proposed UIC program includes single-point resistivity logs to test casing joints, and cement pressure tests to verify the quality of cement grouting the casings to the bedrock. HRI's proposed testing program would be required by NRC license condition.

Wells not passing integrity tests would commonly be reworked and tested again. HRI states that wells repeatedly failing the integrity test would not be considered operational. However, in order to ensure protecting public health and safety, HRI would be required by license condition to plug and abandon all such holes in accordance with New Mexico State Engineer requirements. Additionally, the license would require HRI retest wells after any servicing that could cause casing damage. Repeated integrity testing would also be required every 5 years for all operating wells.

HRI proposes to use high-density polyethylene (HDPE) for its well field distribution pipelines, which would lie mainly on the surface. This construction technique would expedite routine inspections, early leak detection, and repairs. At road crossings or other high-traffic areas, pipelines would be encased in steel culverts and buried. The proposed pipe material exhibits high chemical resistance, is suitable for operating pressure up to 265 psi, and operating temperature from below freezing to approximately 80°C (180°F). Solution mining typically involves injection pressure less than 100 psi, and operating temperatures between 13 and 38°C (55 and 100°F). The operating temperature and processing flow rate would prevent freezing in the surface pipelines during winter.

All well field piping would either be housed in containment buildings or buried at least 0.5 m (20 in.) below the surface. Typically, each well would be connected to the respective injection or production manifold using polyethylene or polyvinyl chloride (PVC) pipe and fittings. Manifolds, located in small containment buildings, would direct solution between individual wells and pipelines to the recovery plant. Meters and control valves in individual well lines would monitor and control flow rates and pressures for each well. Additionally, the entire injection and production system would be metered on the trunk lines for continuous monitoring in the processing plant. This system would be pressure-tested for mechanical integrity in a fashion similar to the wells.

2.1.1.2 Lixiviant Chemistry

Uranium, present in the host ore in a reduced insoluble form, would be oxidized and dissolved by the lixiviant solution injected into the ore zone. Once uranium is oxidized, it easily complexes with bicarbonate anions in the groundwater, and becomes mobile. Table 2.2 shows the anticipated concentrations of the principal chemical species in HRI's pregnant lixiviant from the well fields for processing.

HRI proposes to use a lixiviant solution composed of bicarbonate ion complexing agents and added dissolved oxygen. Uranium compounds contained in mineralized grain coatings would first become

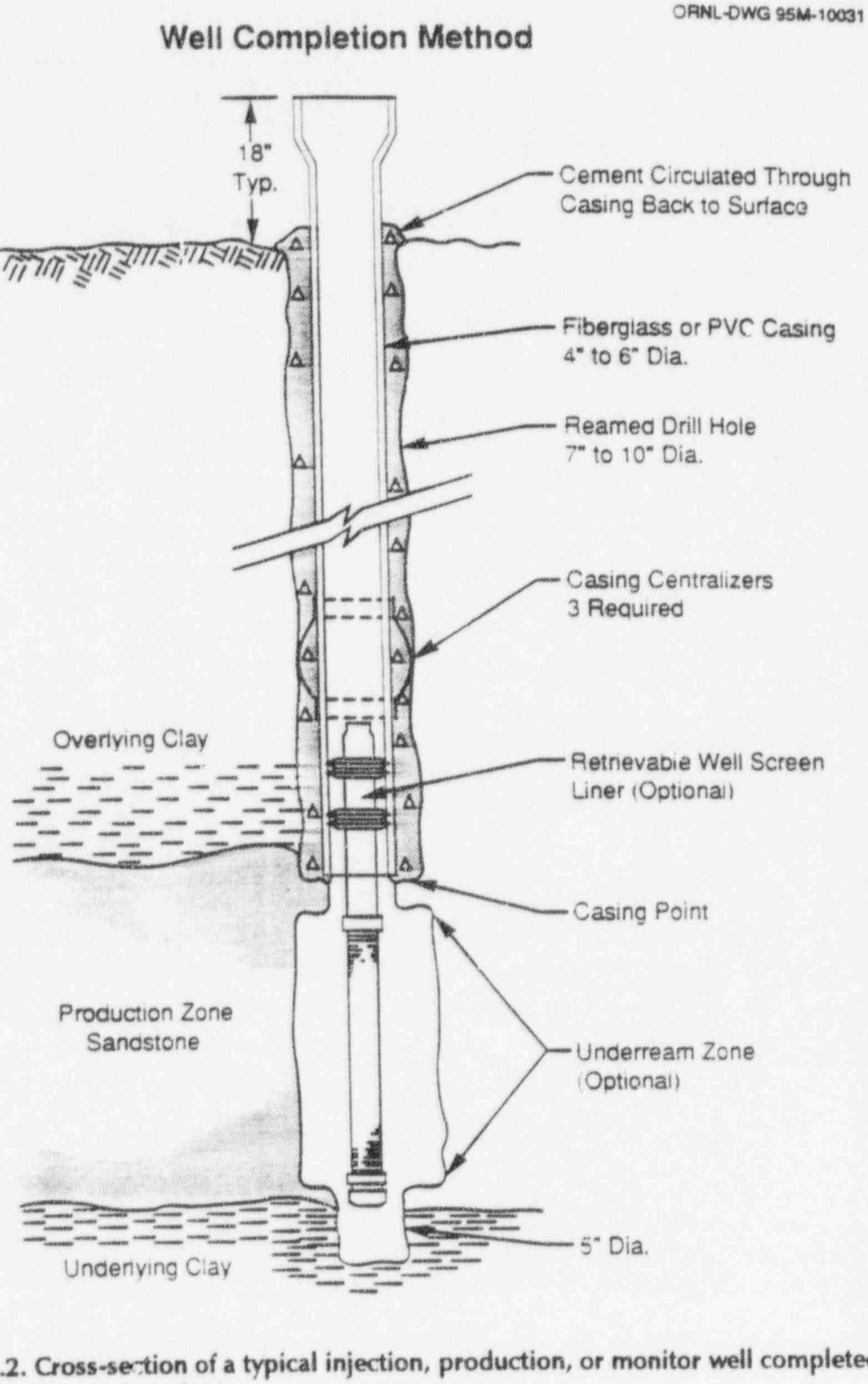

Figure 2.2. Cross-section of a typical injection, production, or monitor well completed using the under-reamed method.

Table 2.2. Anticipated concentrations of principal chemical species in HRI's pregnant lixiviant from the well fields for processing.
[Data are from HRI 1993, test data, and operational licensing experience.]

Chemical species	Concentration (mg/L)
Calcium	100–350
Magnesium	10–50
Sodium	500–1600
Potassium	25–250
Carbonate	0–500
Bicarbonate	800–1500
Sulfate	100–1200
Chloride	250–1800
Nitrate	<0.01–0.2
Fluoride	0.05–1
Silica	25–50
Total dissolved solids (TDS)	1500–5500
Uranium	50–250
Radium-226 (pCi/l)	1000
Other parameters	
Conductivity (μmohs/cm)	2500–7500
pH (standard units)	7.0–9.0

oxidized (Table 2.3, reaction 1). Then, the oxidized uranium would react with the lixiviant to form either a soluble uranyl tricarbonate complex, shown in reaction 2a, or a bicarbonate complex shown in reaction 2b.

Table 2.3. Principal chemical reactions taking place in the ore body during uranium oxidation

(1) $2UO_2 + O_2 \text{———>} 2UO_3$
(2a) $UO_3 + Na_2CO_3 + 2NaHCO_3 \text{———>} Na_4UO_2(CO_3)_3 + H_2O$
(2b) $UO_3 + 2NaHCO_3 \text{———>} UO_2(CO_3)_2^{2-} + H_2O + 2Na$

HRI would pump uranium-enriched pregnant solution from production wells to the processing plants for uranium extraction by ion exchange. The resulting depleted or barren lixiviant would then be chemically refortified and reinjected into the well field to repeat the leaching cycle.

HRI anticipates using production flow rates of 9500 to 11,500 liters per minute (Lpm) [2500 to 3000 gallons per minute (gpm)] at each ion exchange plant. Potential emissions at each plant were conservatively modeled assuming a maximum flow rate of 15,000 Lpm (4000 gpm), and HRI would be restricted from exceeding this rate by license condition. The injection pressure at the well head would not

exceed 0.40 psi per foot of well depth. During normal operations, production rates would be controlled to bleed approximately 1 percent of the production fluid stream. The production bleed would reduce the hydraulic pressure within the mine-unit aquifer and prevent mining solutions from migrating outward.

2.1.1.3 Processing Plant Facilities

At each of the three sites, HRI proposes both to build new facilities and/or convert existing surface facilities from former underground mines into ISL processing plants. Uranium recovery would require columns containing ion exchange resin, vessels to store various solutions, piping, and pumps. The proposed process flow involves pumping lixiviant through the columns and then returning it to the injection circuit. The ion exchange system would be operated in a closed system under low pressure. When uranium is removed from the resins, the concentrated uranium solution would be stored in precipitation tanks. The yellowcake slurry that would be produced in the precipitation tanks (and trucked from the Church Rock and Unit 1 facilities to the Crownpoint facility) would then enter a drying and packaging process at the Crownpoint facility. In the drying and packaging process, the yellowcake slurry would be dewatered, washed, dried, and packaged for storage and final shipment.

HRI's processing plants would include the following major structures:

- A processing plant, in which uranium extraction and precipitation equipment would be located;
- At the Crownpoint facility, a dryer building that would house the yellowcake dryer and drum packing unit;
- Waste retention ponds;
- Waste-water treatment facilities; and
- Administrative offices, laboratories, and workshops.

The satellite processing facilities at Church Rock and Unit 1 would produce only yellowcake slurry, but the Crownpoint plant would also include drying and packaging equipment (Figure 2.3). Under an NRC license condition, all yellowcake would be stored inside the restricted area. Liquid oxygen tanks would be located in the well fields. Other chemical storage tanks would be located on the concrete pad near a waste retention pond.

The main (Crownpoint) and satellite (Church Rock and Unit 1) processing plants would contain various vessels to hold and process liquid solutions. The principal vessels would include ion exchange columns, elution columns, and yellowcake precipitation tanks. Other surge tanks would hold barren lixiviant before its injection in the well fields, barren eluant, and yellowcake slurry. HRI's proposal includes general specifications for all vessels and piping. The specifications cite applicable American Society for Testing and Materials (ASTM) standards for plastic and fiberglass components, and American Society of Metallurgical Engineers (ASME) guides for all steel vessels that would be operated under pressure.

The processing plants would be constructed on concrete pads 20 cm (8 in.) thick with curbs 15 cm (6 in.) high. HRI designed the foundation to retain the fluid contents of the largest vessel on the pad. According to that design, the foundation would be constructed with sumps and drains to catch and retain potential spills inside the plant. Thicker footings would be provided where heavy processing equipment and vessels would be located. The curb would be designed to confine and hold potential spills in the plant, so they could be pumped into storage tanks or retention ponds.

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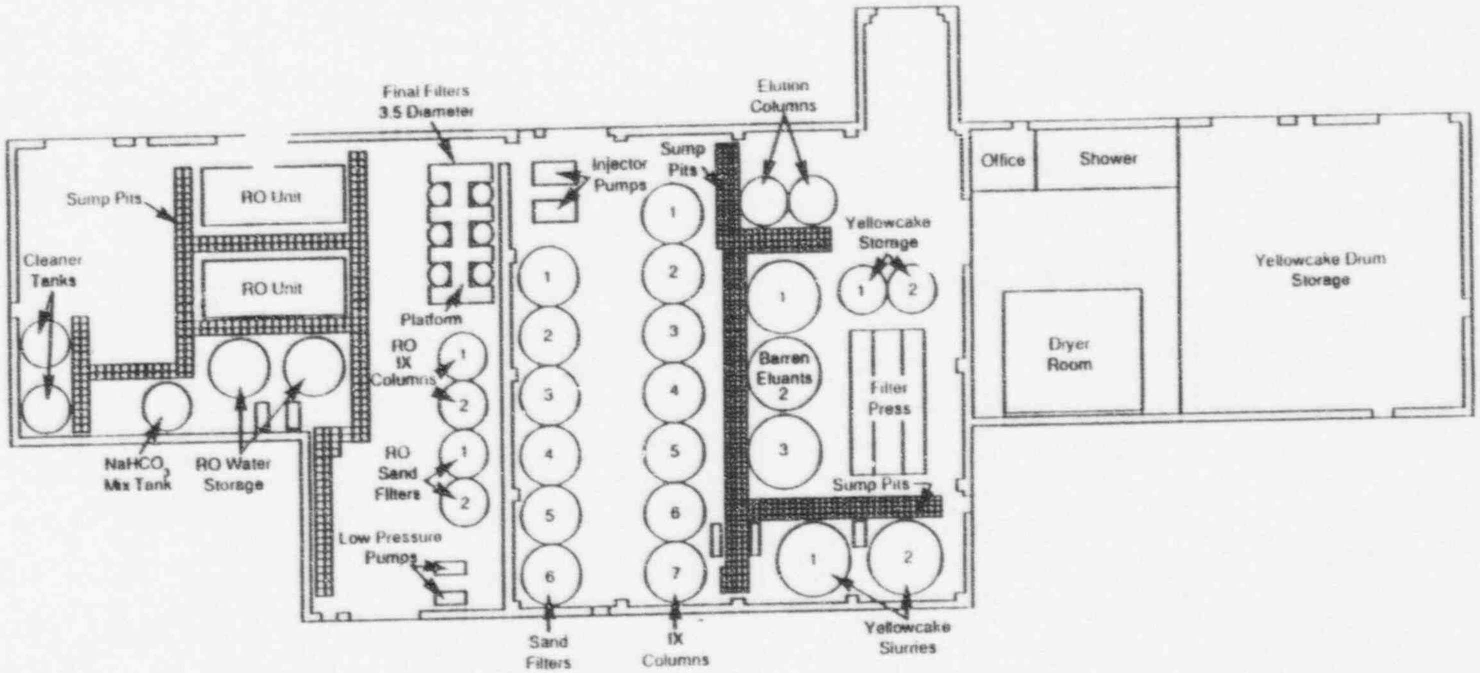

Figure 2.3. Layout of the main processing plant. Satellite ion exchange plants would be identical, but without the dryer and yellowcake storage area.

2.1.1.4 Uranium Recovery Process

During the solution mining process, HRI would add oxygen to groundwater. Combined with naturally occurring and added bicarbonate ions in the groundwater, this mining solution, known as lixiviant, would be pumped down injection wells into the mineralized zones where it would dissolve uranium from the sandstone formation (Figure 2.4). The uranium-bearing solution would migrate through the pore spaces found in the sandstone, and would be recovered from production wells. The uranium would then be extracted in the processing plant, and the leaching solution would be recharged and reused.

Uranium solution would be transferred from mining units to ion exchange equipment in the processing plants. The process, schematically illustrated in Figure 2.5, would involve an ion exchange circuit, an elution circuit, and precipitation and drying.

During mining, the well field water would be enriched with uranium and other minerals associated with the bedrock. Earlier licensing experience indicates that concentrations of trace metals such as arsenic, selenium, vanadium, iron, and manganese may become elevated during the leaching process. Uranium concentration in the pregnant lixiviant from individual production wells could exceed 100 milligrams per liter (mg/L). The nominal concentration in lixiviant would be 60 mg/L. Once the solution reaches the plant, it would be processed through the three circuits discussed above.

In the ion exchange circuit, the solution would be stored in a surge tank or pumped directly into a series of ion exchange columns. It is here that the uranium would be absorbed by ion exchange onto resin beads. The resulting barren solution exiting the ion exchange columns would be recharged with sodium bicarbonate if needed, distributed back to the well fields, and injected with oxygen for further uranium recovery.

As resins in the ion exchange columns become saturated with uranium, each column would be sequentially taken off stream for the elution circuit. In the processing plants, resin could either be eluted in its ion exchange column or transferred to an elution tank. During elution, the uranium would be stripped by flushing the resin beads with concentrated brine solution. The resin beads, then virtually free of uranium, would be replaced in an ion exchange column for reuse. The resulting pregnant eluant, which would contain the uranium stripped from the resin beads, would be discharged into a holding tank. The concentration of uranium in the pregnant eluant would be approximately 20,000 mg/L. When a sufficient volume of pregnant eluant is held in storage, the final precipitation and drying circuit would begin.

Pregnant eluant would be acidified using hydrochloric acid (HCl) to destroy the uranyl carbonate complex. Hydrogen peroxide would then be added to the solution to precipitate the uranium. The precipitated uranyl peroxide slurry (UO4 or yellowcake) may require pH adjustment, and then would be allowed to settle. At the Crownpoint facility, yellowcake would be further dewatered and washed using a filter press and then dried. Water left over from dewatering and drying would either be reused in the elution circuit or directed to a wastewater retention pond. HRI's proposed operations would result in maximum yearly production rate of 3 million pounds of yellowcake.

At the satellite ion exchange plants, the resins would be eluted and the uranium precipitated and filtered. The resulting yellowcake slurry would be transported by truck to the main Crownpoint facility for drying (Figure 2.6). HRI's proposal indicates yellowcake would be transported to the Crownpoint processing plant in sole-use semi-trailer tankers designed and placarded for this purpose, in accordance with U.S.

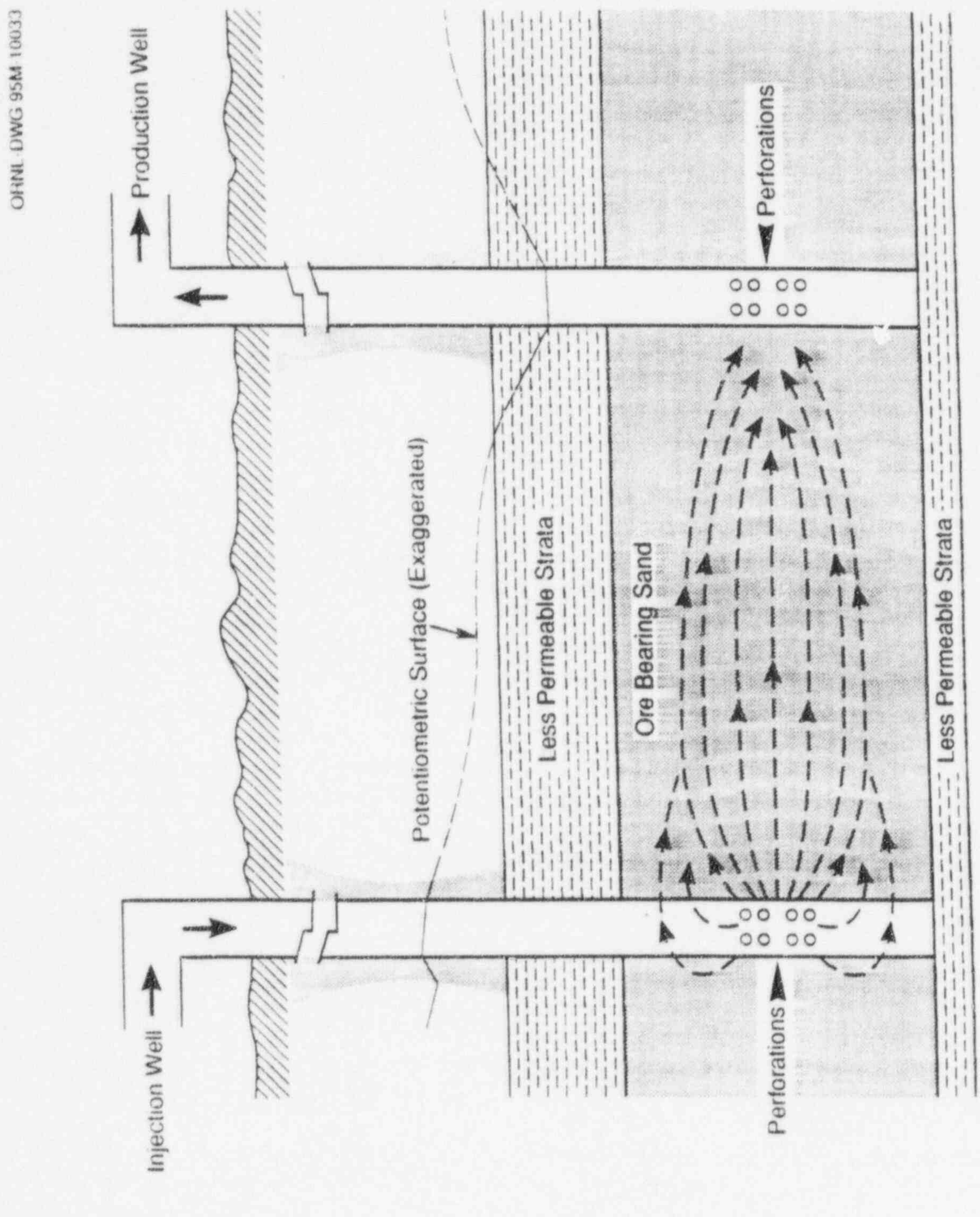

Figure 2.4. Schematic cross-section illustrating ore-zone geology and lixiviant migration from an injection well to a production well.

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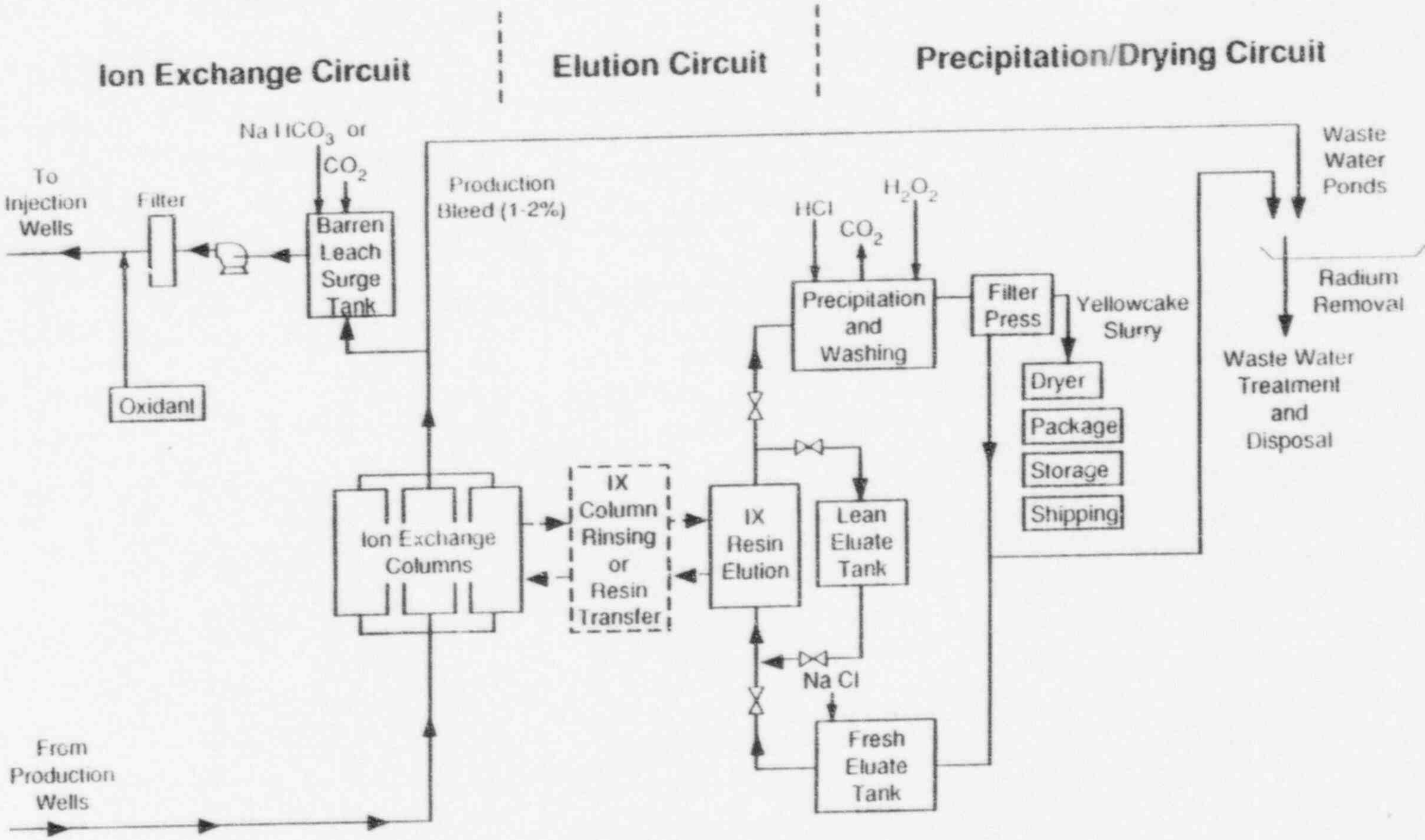

Figure 2.5. Schematic flow diagram of the ISL uranium recovery process.

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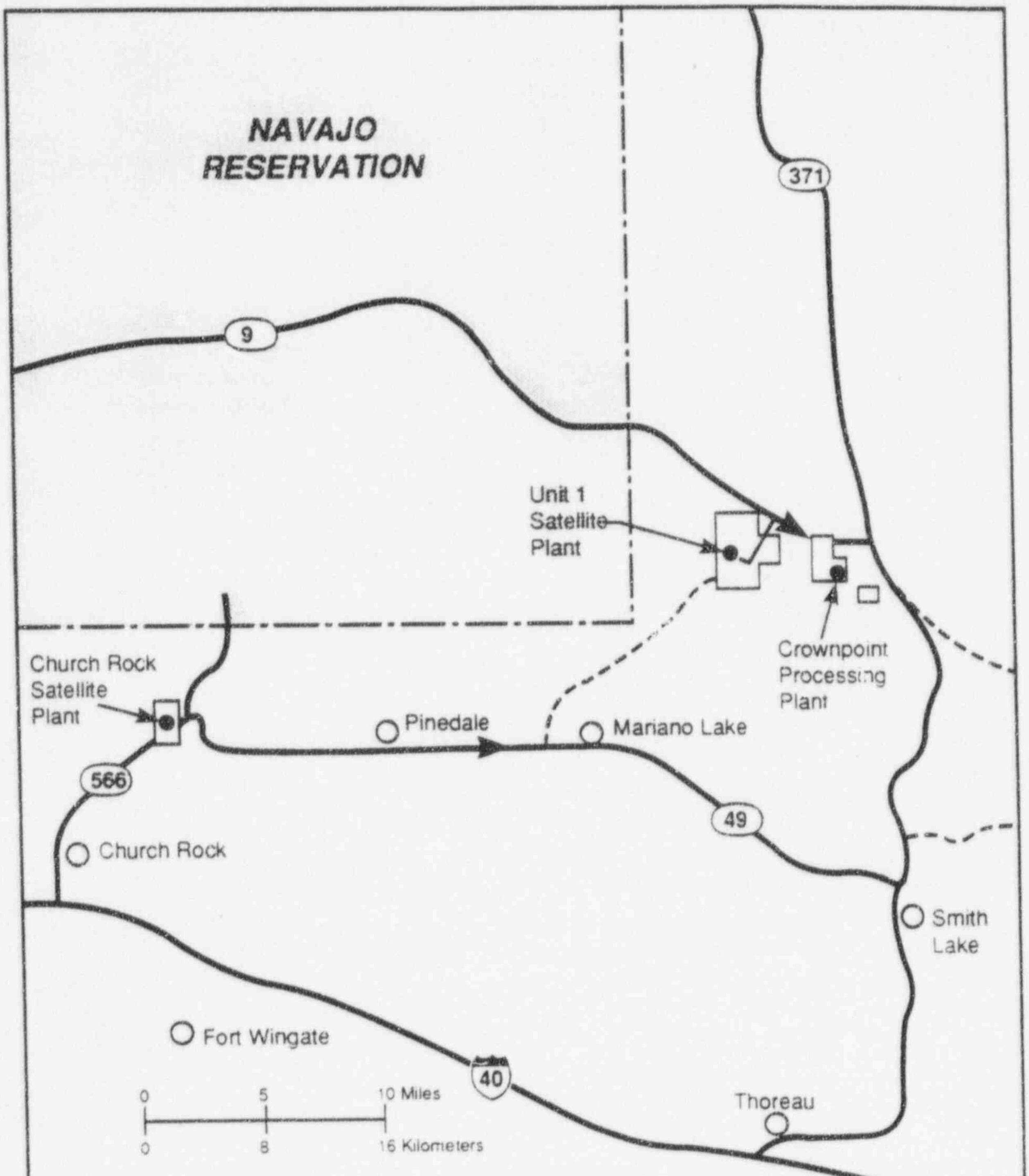

Figure 2.6. Haul routes for yellowcake slurry from satellite plants to the Crownpoint Plant.

Department of Transportation requirements. The transportation route would use only paved roads and would bypass the center of the town of Crownpoint.

2.1.1.5 Waste Retention Ponds

The purpose of retention ponds is to store wastewater until treatment, promote evaporative loss of water which cannot be discharged to the environment, and maintain control of source and byproduct material found in the liquid effluents from solution mining. HRI proposes to use three waste retention ponds at each processing site. These ponds, which would occupy approximately 2.5 ha (6 acres) each, would be constructed below ground level to maintain all processing solutions below grade. HRI commits to designing and constructing its pond embankments to meet specifications in NRC Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills" (NRC 1977a), in the event that pond operating levels above grade are required. HRI would be required by license condition to perform and document inspections of the pond embankments, fences, and liners, as well as measurements of pond freeboard and checks of the leak detection system.

The ponds would have double synthetic liners and an intervening layer up to 18 cm (6 in.) thick containing sand and perforated piping forming an underdrain leak detection system. An acceptable design alternative would eliminate the intervening sand blanket, replacing it with synthetic grid material.

If increased waste storage and evaporation pond capacity becomes necessary, HRI would be required either to provide additional pond area, or to construct the ponds with above-grade embankments and storage levels. Therefore, HRI would be required by license condition to maintain fluid levels below grade, or to construct its ponds in accordance with NRC Regulatory Guide 3.11 "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills" (NRC 1977a), or other acceptable design criteria.

2.1.1.6 Instrumentation

HRI proposes to monitor its production system both in the well fields and the processing plants. The metering system would permit continuous pressure monitoring on both the injection and production pipeline systems, and would provide audible alarms for plant operators in the event of leaks or ruptures. Formal visual inspections would be conducted and documented twice during each 12-hour shift. Additionally, mining company personnel who would conduct routine construction and maintenance in the well field areas would provide well field surveillance. HRI commits to providing its plants with sumps and pump equipment to prevent any potential spills from escaping the processing pad.

In the yellowcake drying area at the Crownpoint facility, HRI proposes to periodically inspect the entire dryer system and check the integrity and efficiency of the vacuum system, fabric bag filter unit, and heating system. An NRC license condition would require that HRI suspend yellowcake drying operations if emission control equipment is not operating within specifications for design performance. Additionally, HRI would be required to maintain manufacturer recommended pressure in the drying chamber by (1) performing and documenting checks of air pressure differential during operation, or (2) installing instrumentation that would provide an alarm if the air pressure differential falls below the manufacturer's recommended levels.

Routine environmental monitoring would be conducted independently of operational monitoring. HRI's proposed environmental monitoring systems are based on an outline provided in NRC's Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills" (NRC 1980b).

HRI's proposed plant monitoring and documentation system (including associated routine and nonroutine reporting procedures) would be required by NRC license conditions. In-plant radiation monitoring and occupational safety programs would be reviewed and approved by the NRC.

2.1.2 Description of the Proposed Waste Management and Effluent Control System

Solution mining produces two principal types of effluents that could potentially be released to the environment. These are the gaseous emissions and airborne particulates resulting from lixiviant circulation and yellowcake drying, and wastewater from well field processing and aquifer restoration. Other contaminated materials, produced largely during site decommissioning, would also require appropriate disposal. HRI has not applied and would not be authorized to dispose of radiologically contaminated source or byproduct waste material onsite in any of the proposed lease areas.

2.1.2.1 Gaseous Effluents and Airborne Particulates

Uranium recovery operations potentially release radon gas at various stages of the processing system, and natural uranium and other particulates from the yellowcake dryer. These substances are naturally occurring in the ore body, and are found dissolved in the groundwater circulated to the surface during the mining process.

HRI proposes to minimize radon releases by employing a closed pressurized well field and ion exchange system. Radon gas dissolved in circulating lixiviant would be kept in solution by maintaining pressure on the system. Excessive vapor pressure could accumulate, mainly from dissolution of carbon dioxide or oxygen in the circulating lixiviant. These gasses, along with some radon, would then be vented by relief valves. These relief valves would be installed at numerous outdoor locations on the trunk pipelines to disperse radon emissions and prevent accumulation in any one area. The ion exchange vessels would provide a closed system, and vents typically found in such vessels at other uranium recovery facilities would not be installed.

The only major radon release from the plants would occur when individual ion exchange columns are opened for resin transfer or elution. At this stage of the process the contents of one ion exchange column would be transferred to open eluant or precipitation vessels. Potential radon releases here would be limited to the fixed quantity of radon found dissolved in the water contained in one ion exchange column. Radon escaping from the solution would be vented from the vessels through the ventilation system of processing buildings. Under NRC license conditions, all effluent releases would be subject to release limits specified in 10 CFR 20, as well as occupational and environmental programs. In-plant monitoring would verify that safe radon working levels are maintained in the plant.

The largest potential source of radon emissions from the proposed facilities is wastewater. Typically, radon dissolved in wastewater would equilibrate with atmospheric pressure upon discharge into a retention pond. Combined with turbulence caused by the pond discharge outlet, radon gas would come out of solution and escape to the atmosphere. HRI proposes to eliminate this radon source by removing it in intermediate

holding tanks using a vacuum pump, compressing the gas, and dissolving it in the lixiviant injection system. Radon would then be recirculated in the mining solution, and carbon dioxide emissions would be put to use by augmenting the carbonate content of the lixiviant.

HRI proposes to use vacuum dryer technology in its yellowcake drying and packaging system at the Crownpoint facility. In a vacuum dryer, the heating source is contained in a separate, isolated system so no radioactive materials are entrained in the heating system or the exhaust it generates. The drying chamber containing yellowcake slurry would be subjected to strong vacuum pressure, thereby sealing all entryways into the drying chamber. Moisture in the yellowcake would be the only source of vapor remaining in the system. Any potential leak would result in outside air flowing into the drying chamber.

Emissions from the drying chamber would be treated in two phases. First, all water vapor would be drawn through a bag filter to remove yellowcake particulates with an efficiency exceeding 99 percent. Captured particulates would be returned to the drying chamber. Second, using a condenser all water vapor from the drying chamber would be cooled and condensed. The vapor stream is drawn through a water jacket and condensate, thereby capturing virtually all particulates escaping the bag filter. The condensate would then be returned to the uranium precipitation circuit in the plant. This technology would result in zero emissions, and require no ventilation from the drying chamber to the atmosphere.

2.1.2.2 Liquid Effluents

Both the satellite and the main processing facilities would generate liquid and solid wastes. The largest cumulative waste stream at each plant would occur as production bleed during uranium recovery. HRI estimates that its production bleed rate at each plant would amount to 1 percent of the flow rate. Operating at full licensed capacity, each lease area would produce wastewater at a rate of 40 gpm.

HRI proposes to treat production bleed to remove radium, and then conduct additional treatment to purify the bulk of the wastewater, concentrating other contaminants in a small volume. Purified water would then be used in the plant to supply processing water, and the remainder could be discharged using an approved disposal method.

Discontinuous liquid waste streams stemming from production would include periodic flushing of depleted eluant to reduce accumulated impurities. Another waste stream would result from uranium precipitation and filter washing; the stream would likely be contaminated with dilute hydrochloric acid. These wastes would be collected, retained, and treated in a brine concentrator.

During aquifer restoration, HRI proposes to produce degraded groundwater at rates between 570 and 950 Lpm (150 to 250 gpm). Restoration would be accomplished by combining groundwater sweep and permeate injection. All water drawn from the aquifer would be processed to remove uranium, then treated with barium chloride (BaCl) to remove radium. HRI proposes to then conduct additional treatment to purify the bulk of the wastewater, and concentrate remaining contaminants in a small volume. Purified water would then be used to continue aquifer flushing, or may be released according to an approved discharge plan.

2.1.2.3 Wastewater Treatment

HRI proposes to treat all wastewater streams described above. While water treatment is potentially costly, it would serve several purposes. First, HRI must acquire rights to and purchase all water consumed during this project. Therefore, project costs can be lowered by reducing waste. Second, disposing of wastewater would consume a natural resource, potentially resulting in an adverse environmental impact. Additionally, wastewater treatment would allow it to be released with minimal impact on environmental quality.

Radium Removal. HRI proposes to conduct radium removal using barium chloride treatment. Barium and radium would form an insoluble salt with sulfate already found in the processing solution. Additional flocculent may be added to enhance precipitation and settling. This technology was developed at other uranium recovery projects, and can be conducted in retention ponds or holding vessels inside the processing plants. HRI has documented radium-removal tests conducted on sample mine water from the project area; these tests indicate that more than 99 percent of radium in solution would be removed using the tested techniques (Table 2.4). The treatment technology results in radium concentrations below one percent of federal limits for releases to waterways. The success of this treatment method would be monitored by daily water sampling.

Table 2.4. Applicant's data on barium chloride treatment for removing radium from wastewater (HRI 1988)

	BaCl concentration (mg/l)	Final radium concentration (pCi/l)
Test 1	0.0 (waste stream)	74.0
	10.5	0.21
	14.0	0.24
	17.5	0.24
Test 2	0.0 (waste stream)	73.4
	10.5	0.66
	14.0	0.28
	17.5	0.40
Test 3	0.0 (waste stream)	73.4
	14.0	0.20
	17.5	0.64

Radium-contaminated sludge in ponds resulting from water treatment would require disposal as solid byproduct waste material. These waste materials would be collected in barrels or as bulk slurry, and transported to a licensed byproduct waste disposal facility. No permanent byproduct radioactive waste disposal would be authorized at any of the three project sites.

Reverse Osmosis. Reverse osmosis is a water treatment technique that splits a wastewater stream, purifying one portion of the stream, and concentrating contaminants in the other. The process works by pumping wastewater under high pressure through low-permeability membranes. Water molecules can pass

through the membrane, while most dissolved and suspended chemicals cannot. The water passing through is known as permeate. Depending on how the process is conducted, the water can become essentially deionized. Meanwhile, the chemical constituents become increasingly concentrated in the portion of the water that does not pass through the membranes. The result is a volume of clean water, and a reduced volume of more highly degraded briny water.

Reverse osmosis typically concentrates contaminants in approximately one-third of a water stream, while purifying the remaining two-thirds. HRI proposes to retain the reverse osmosis brine for further treatment and concentration of contaminants, as described in the next section. The clean permeate would be released as described in Section 2.1.2.4.

Brine Concentration. Brine resulting from reverse osmosis water treatment would be processed again through a sophisticated water distiller known as a brine concentrator. This concentrator would work by heating and evaporating the waste brine, then condensing the water vapor as pure water. The highly concentrated brine would largely consist of precipitated solids in the form of common salts.

Together, reverse osmosis water treatment and brine concentration would produce approximately 1 part of briny slurry and salt solids from each 300 parts of wastewater. The brine sludge would be held in a lined retention pond and kept moist enough that solids would not become suspended in the air. The remaining larger volume of purified wastewater can then be released according to an approved discharge plan.

2.1.2.4 Liquid Waste Disposal Options

The solution mining industry has used various disposal methods for liquid waste streams, including evaporation ponds, deep-well injection, land application, and surface discharge under a National Pollution Discharge Elimination System (NPDES) permit. Each of these disposal methods is used to varying degrees in the industry for defined waste streams. Under NRC license condition, HRI would treat all of its wastewater streams, releasing only treated water that meets NRC's release limits for radionuclides (10 CFR 20). The State of New Mexico would require that any wastewater released in a land application system meet state standards for irrigation water. Authorization to use surface discharges or deep-well disposal would require separate permits, and is not requested in HRI's proposal. To ensure that all liquid wastes are accounted for, HRI would be required by NRC license condition to return all liquid effluents to the process circuit or an approved disposal system.

Evaporation Ponds. Evaporative loss from ponds, the most commonly used water disposal technique at solution mines, is typically used for all waste streams. Additionally, it is the most conservative technique because it concentrates and maintains all byproduct materials in a sludge that is then disposed of in a licensed disposal site. This disposal method is also the most costly. It requires lined ponds equipped with leak detection systems, as well as additional handling and transporting of the resulting sludges.

HRI estimates 40 ha (100 acres) of evaporation ponds would be required in each lease area. All of this land would be significantly disturbed by construction, and would potentially require decontamination during decommissioning.

Deep-Well Injection. Deep-well injection is a popular disposal method among mining companies. This method uses specially drilled wells to dispose of liquid wastes. These wells typically extend deeper than

1525 m (5000 ft), are well below any usable aquifer, and are commonly completed in a horizon where groundwater is not suitable for drinking. An acceptable stratigraphic unit for deep-well disposal would contain a deep, confined aquifer with water quality degraded by more than 10,000 mg/l total dissolved solids. HRI considers that the Abo or Yeso Formations, underlying the sites approximately 1570 to 1645 m (5150 to 5400 ft) deep, most likely meet these criteria. At other solution mines, reverse osmosis brine is most commonly injected into these wells. Disposal by deep-well injection would require an injection well permit granted by the EPA or the State of New Mexico. Use of a deep injection well would require an NRC license amendment after the injection well permit was granted.

Land Application. Land application is a disposal technique that uses agricultural irrigation equipment to broadcast wastewater on a relatively large area of land. The main environmental considerations are salt accumulation in the root zone, affects on native plant growth, and potential food pathways for radionuclides through the plants to animals and humans.

Land application is currently authorized at several solution mines. Water released in this fashion would require uranium and radium removal as described above. At each site, irrigation would be restricted to the lease areas held by HRI, and would be regulated by irrigation standards adopted by the State of New Mexico, Environmental Department. In addition, NRC would require HRI to decontaminate areas if radionuclides or trace metals accumulation exceeds decommissioning standards.

HRI's application specifies that on-site land application could occur on 22 ha (54 acres) in the southeastern portion of the Church Rock lease area, and on two tracts of land totaling 35 ha (85 acres) in its Unit 1 and Crownpoint lease areas. HRI characterizes the affected soils in the Church Rock area as sandy loam or sandy clay loam. These soils, described by the U.S. Soil Conservation Service, are at least 1 m (40 in.) deep, well drained, and characterized by low sodium absorption ratios. HRI claims that these characteristics favor land application because they would not promote accumulation of sodium salts.

Off-site land application for the Church Rock site could occur on 256 ha (640 acres) in Section 16, T16N R16W east of the Church Rock site. Off-site land application for the Crownpoint and Unit 1 sites could occur on 256 ha (640 acres) in Section 12, T17N R13W north of the Crownpoint and Unit 1 sites.

Surface Discharge. The final disposal method utilized by the solution mining industry is surface discharge, requiring authorization by the EPA or the State through an NPDES permit. This disposal method has only been used for discharging treated water, but has been considered by licensees for other waste streams. Generally, radionuclides in wastewater authorized for this method of disposal are subject to release limits found in NRC regulations.

HRI's Proposal. HRI proposes to treat all wastewater resulting from both well field production and aquifer restoration. Uranium would be removed using ion exchange. Radium would be removed in settling ponds or closed vessels using BaCl treatment. Other chemical constituents found dissolved in the wastewater would become concentrated in a relatively small quantity of briny sludge, using a combination of reverse osmosis treatment and brine concentration. Using this combination, 4 liters (1 gallon) of brine sludge would remain for every 1200 liters (300 gallons) or so of treated wastewater.

HRI would retain the radium wastes as byproduct material, requiring disposal at an NRC-licensed facility. Excessive radionuclide or trace metal contamination in the brine wastes would result in classifying those wastes as byproduct material, requiring disposal in an NRC-licensed waste facility.

The treated water would be nearly pure. HRI proposes to handle this waste stream by reinjecting it into mine units to promote aquifer restoration. Excess treated water could be land applied inside the proposed lease areas. HRI also proposes to reinject the excess clean water back into the Westwater Canyon sandstone, but outside the mining area. This proposal would require an injection well permit granted by either the EPA or the State of New Mexico. Injecting treated wastewater outside the mining area would require an amendment to the NRC license, after the injection well permits are granted by the appropriate agency.

2.1.3 Restoration, Reclamation, and Decommissioning

Following uranium recovery in each mine unit, HRI would be required by NRC license to restore groundwater quality. At the conclusion of the project, all contaminated materials, soil, and structures would be removed from the sites. The facilities would then be decommissioned, and the well field and processing plant sites would be reclaimed. The following sections provide details regarding standards which would be met, and the procedures used to meet them.

Detailed restoration, reclamation, and decommissioning plans, related cost estimates, and an appropriate surety would be required by NRC license condition before HRI could begin uranium recovery operations. NRC regulations require that the licensee maintain an adequate financial surety in the form of surety bonds, cash, certificates of deposit, deposits of government securities, or irrevocable letters of credit to cover the costs for decommissioning, reclamation of the disturbed areas, waste disposal, and groundwater restoration. The amount of the surety is based on cost estimates for completing the approved reclamation plan by a third party in the event the licensee defaults. The surety is reviewed annually by NRC and adjusted to reflect expansions in operations, changes in engineering design, and inflation.

2.1.3.1 Aquifer Restoration

Consistent with current ISL restoration practices, the primary goal of restoration is to return to baseline conditions all groundwater affected by the mining. Table 2.5 presents the list of constituents for which HRI's proposes to monitor restoration success. Before mining, HRI proposes to establish baseline groundwater quality in selected wells in the production zone, perimeter monitor wells, and monitor wells in overlying aquifers. Approved procedures for baseline determination would be specified in an NRC license condition. All baseline groundwater data would also be subject to review and approval by the NRC before HRI would be authorized to inject lixiviant in any mine unit. In addition, HRI would be required to use baseline conditions as the primary restoration target for all constituents.

HRI proposes to restore the aquifers using techniques called groundwater sweep and permeate injection (Figure 2.7). Groundwater sweep involves flushing the aquifer with naturally occurring groundwater and decontaminated water to remove any remaining lixiviant and degraded groundwater. Affected water in each mine unit being restored would be withdrawn at flow rates of 570 to 950 Lpm (150 to 250 gpm), processed through ion exchange to remove uranium, then treated to remove radium and dissolved solids. This treated water, known as permeate, would then be reinjected to further flush the aquifer. Groundwater sweep and

Table 2.5. Applicant's proposed list of chemical constituents to be analyzed in each monitoring well for restoration purposes

A. Common constituents (in mg/L)

Ammonia	Magnesium
Bicarbonate	Potassium
Calcium	Silica
Carbonate	Sodium
Chloride	Sulfate
Fluoride	Nitrate

B. Trace and minor elements (in mg/l)

Arsenic	Manganese
Barium	Mercury
Boron	Molybdenum
Cadmium	Nickel
Chromium	Selenium
Copper	Silver
Iron	Uranium
Lead	Vanadium
Radium-226 (pCi/l)	Zinc

C. Physical parameters

Total dissolved solids—mg/l
Alkalinity—mg/l
Specific conductivity—μmhos @25°C
pH—standard units

permeate injection would be balanced so that a cone of depression would be maintained, causing groundwater to flow into the mining unit. Thus, natural groundwater would be drawn into the mining unit's center.

2.1.3.2 Land Reclamation

When the project is fully operational, only certain portions of the proposed mine area would be in production. Therefore, reclamation would occur in interim steps to minimize environmental impacts during and after mining takes place, and would restore disturbed land to its pre-mining use. A license condition would require HRI to submit a final decommissioning plan for NRC review and approval at least 12 months prior to license termination.

The most prominent surface disturbance would occur at solution storage ponds. Additional land disturbance would be necessary for well drilling, pipeline installation, and road construction, but these disturbances would be less extensive. In addition, all disturbed areas would be subject to HRI's proposed

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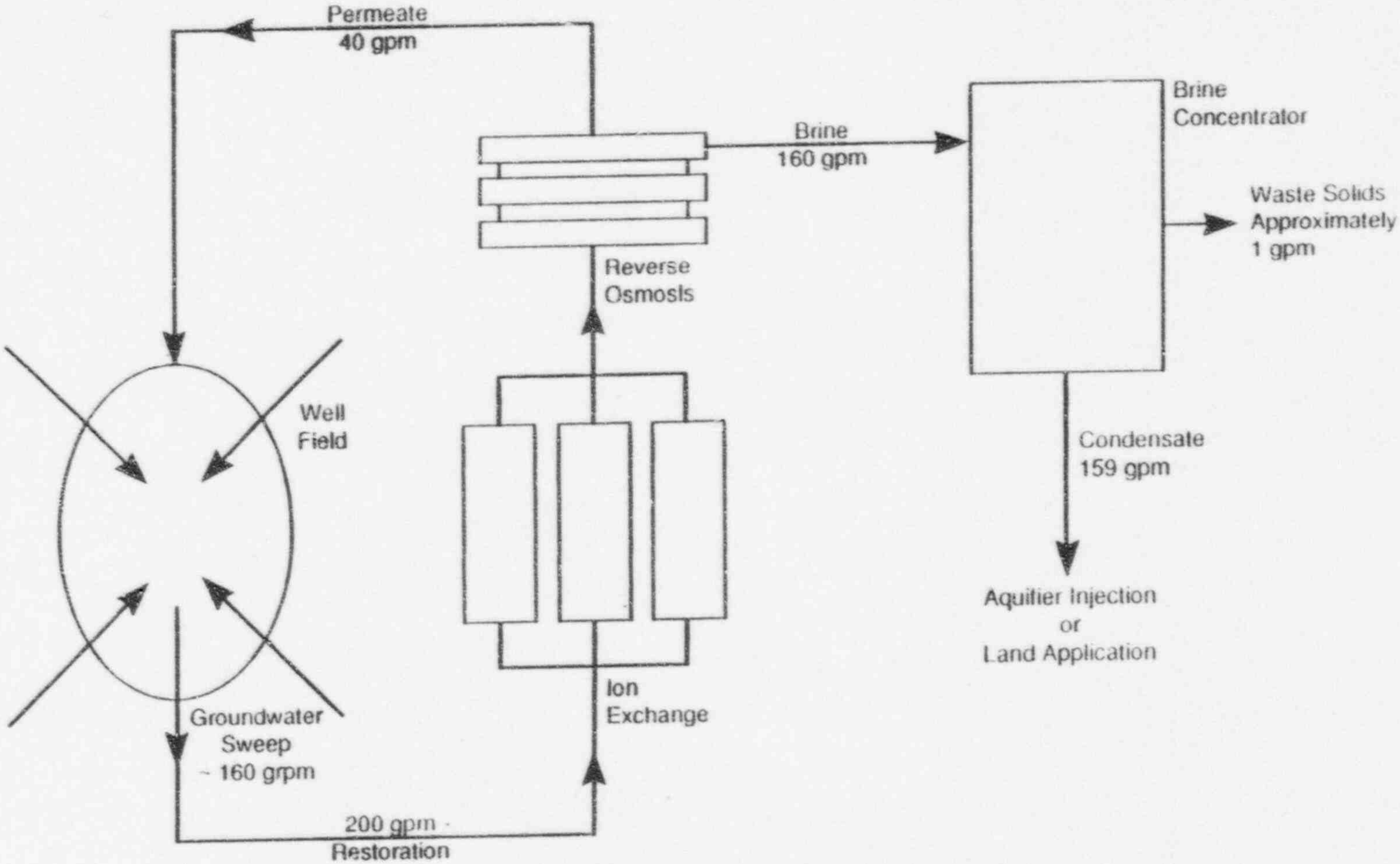

Figure 2.7. Schematic flow diagram and approximate flow rates of restoration wastewater treatment systems.

site reclamation plan. Many of the foundations, buildings, storage areas, and parking lots for the processing plant already exist at the Crownpoint site.

Topsoil Handling. Soil disturbances caused by the mining operation would be kept to a minimum. Topsoil from existing mine facilities is already stockpiled. Topsoil from pond areas and other areas requiring significant grading or surface disturbance would be removed, stockpiled and stabilized. Well fields as a whole would not be cleared of vegetation or topsoil. Where concentrated disturbance occurs, such as drilling sites, topsoil would be bladed to one side and then re-spread over the area as soon as construction is completed.

Well Fields. After restoring groundwater in the mined aquifers, HRI would decommission each well field, and remove all well field lines and pipelines. In addition, HRI would plug and abandon injection, production, and monitor wells according to New Mexico State Engineer requirements. After removing pumps and tubing, HRI would backfill each well with an approved cement slurry, and cut the casing 1 m (3 ft) below the surface. HRI would then backfill the wellhead area and would reclaim the surface according to the approved plan.

Pad Reclamation. The plant and pond areas would be reclaimed in a manner similar to that used for well field areas, and would be subject to approval by land owners and/or lessors. First, HRI would remove all contaminated material and pond liners, and return excess soil in pond embankments to the ponds as fill. Next, HRI would reestablish land surface contours and replace topsoil on disturbed areas. A period of several years would be required to establish a viable vegetative cover.

Radiation Surveys. Any equipment or buildings that can be decontaminated to levels acceptable for unrestricted use may be sold and left to be used for other purposes. All other equipment, buildings, foundations, piping, and associated support facilities would be removed, and appropriate radiation surveys would be conducted over the associated areas. In the well fields, where gamma surveys correlate well with actual radiation concentrations in soil, gamma surveys would be conducted as each mining unit is decommissioned. Gamma survey results would be compared with background values, and soil samples would be obtained from locations that exhibit elevated gamma readings. Areas exhibiting elevated uranium and radium-226 levels would be decontaminated in accordance with release limits specified in NRC's regulations. Contaminated soil would be disposed of in the same manner as other radioactively contaminated material. All survey results would be subject to verification by the NRC.

Recontouring. After completing decommissioning and decontamination, HRI would initiate final reclamation. Recontouring the land where disturbance has taken place would restore the surface and provide a terrain consistent with the post-mining land use. In addition, HRI would replace topsoil stockpiles over areas from which they were removed.

Revegetation. HRI proposes to reseed all disturbed areas using plant mixtures selected from eight native plant species, depending on the soil type encountered in various areas. The species include the native grasses and shrubs listed in Table 2.6. Mulch would be used in any area where water retention, soil temperature, or soil crusting prevent suitable seed germination and growth.

Table 2.6. Applicant's proposed seed application rates for reclaimed areas.
All values given in kilograms per hectare (pounds per acre)

	Clay soil	Loamy soil	Sandy soil
Arriba western wheatgrass	7.2 (6.4)	5.4 (4.8)	7.2 (6.4)
Alkali sacaton	0.9 (0.8)	0.8 (0.7)	0.6 (0.5)
Vaughn sideoats grama		2.3 (2.0)	1.8 (1.6)
Paloma indian ricegrass			2.7 (2.4)
Bandera rocky mountain penstemon			0.3 (0.3)
Pastura little bluestem			0.3 (0.3)
Loveington blue grama	0.3 (0.3)	0.7 (0.6)	
Fourwing saltbush	1.4 (1.2)		

2.1.3.3 Plant Decontamination and Decommissioning

Solid wastes generated at the site during operations would consist of spent resin, empty chemical containers, miscellaneous pipes and fittings, contaminated sludge in ponds, and domestic trash. These wastes would be classified as contaminated or noncontaminated waste, according to their radiological survey results. Noncontaminated waste could be disposed of as ordinary trash.

Any contaminated material accumulating at the site during operations or reclamation may be disposed of as byproduct waste material. Alternatively, contaminated equipment could be sold or transferred to another source material licensee. This method would involve minimal decontamination, and all shipments would be subject to U.S. Department of Transportation requirements. No permanent byproduct radioactive waste disposal would be authorized at any of the three project sites.

Contaminated material having no salvage value would be stored in a restricted area until it can be shipped to a licensed waste disposal facility. The project would not generate any "hazardous waste," as defined by the Federal Resources Conservation and Recovery Act (RCRA). Waste disposal plans would be regulated by NRC license conditions.

After the project is completed, equipment from the processing plants would be handled in one of three ways:

- Contaminated equipment may be dismantled and sold or transferred to another licensed facility. Alternatively, equipment decontaminated in accordance with NRC guidance may be sold for reuse, salvage or scrap.
- Decontaminated materials having no resale value, such as building foundations, may be removed for disposal elsewhere or buried on-site.
- Waste materials that cannot be decontaminated would be disposed of in an NRC-licensed facility.

After all liquid in ponds has been eliminated as approved in the license, residues and the pond liners would be removed and disposed of in a licensed facility. Pond liners typically cannot be economically cleaned for unrestricted use. Pond areas would then be reclaimed along with other disturbed areas.

2.1.4 Description of the Proposed Sites

2.1.4.1 The Church Rock Site

The Church Rock mining units and satellite processing facility would be located in Sections 8 and 17, T16N R16W (Figure 2.8), approximately 10 km (6 mi) north of the town of Church Rock. The satellite processing facility would be located in Section 8. HRI's mineral rights include 65 ha (160 acres) of patented mining claims in Section 8, and 80 ha (200 acres) of leases in Section 17. HRI anticipates that uranium recovery activities at the Church Rock site would occur over approximately 8 years.

The Church Rock site covers 145 ha (360 acres), of which approximately 90 percent [130 ha (324 acres)] would be disturbed during project construction and operation. The estimate of 130 ha (324 acres) includes areas that have been previously disturbed as well as those that would be newly disturbed. The satellite processing facility's buildings, plant areas, parking lots, and settling ponds would occupy approximately 2.5 ha (6 acres). Well fields would occupy approximately 32 ha (80 acres). Additional acreage would be required for access roads, on-site wastewater land application areas, and evaporation ponds. If HRI disposes of wastewater using off-site land application (i.e., in Section 16, T16N R16W), an additional area of up to 256 ha (640 acres) could be disturbed. Thus, the total land area that would be disturbed at the Church Rock site ranges from 130 ha (324 acres) (on-site land application) to 386 ha (964 acres) (off-site land application in Section 16).

2.1.4.2 The Unit 1 Site

The Unit 1 mining units and satellite processing facility would be located in Sections 15, 16, 21, 22, and 23, T17N R13W (Figure 2.9), approximately 3.2 km (2 mi) west of the town of Crownpoint. The satellite processing plant, retention ponds, and support facilities would be located in Section 21. The mine plan would initially affect reserves in Sections 21 and 22. HRI anticipates that uranium recovery activities at the Unit 1 site would occur over approximately 17 years.

The Unit 1 site covers 512 ha (1280 acres), of which approximately 70 percent [358 ha (896 acres)] would be disturbed during project construction and operation. The estimate of 358 ha (896 acres) includes areas that have been previously disturbed as well as those that would be newly disturbed. The satellite processing facility's buildings, plant areas, parking lots, and settling ponds would occupy approximately 2.5 ha (6 acres). Well fields would occupy approximately 280 ha (700 acres). Additional acreage would be required for access roads, on-site wastewater land application areas, and evaporation ponds. If HRI disposes of wastewater using off-site land application (i.e., in Section 12, T17N R13W), an additional area of up to 256 ha (640 acres) could be disturbed. Thus, the total land area that would be disturbed at the Unit 1 site ranges from 358 ha (896 acres) (on-site land application) to 614 ha (1536 acres) (off-site land application in Section 12).

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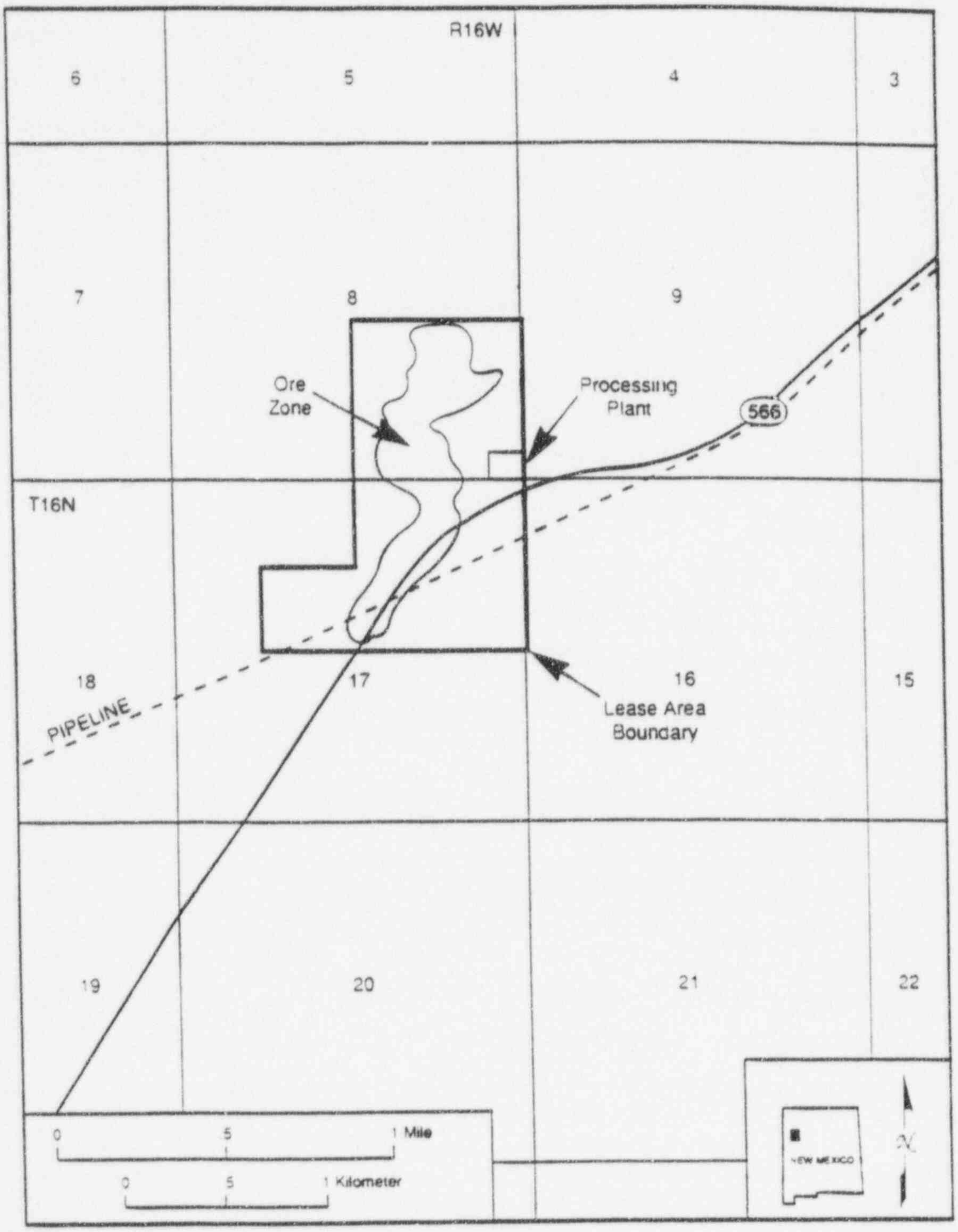

Figure 2.8. Lease area, ore zone, and processing plant locations at the Church Rock site.

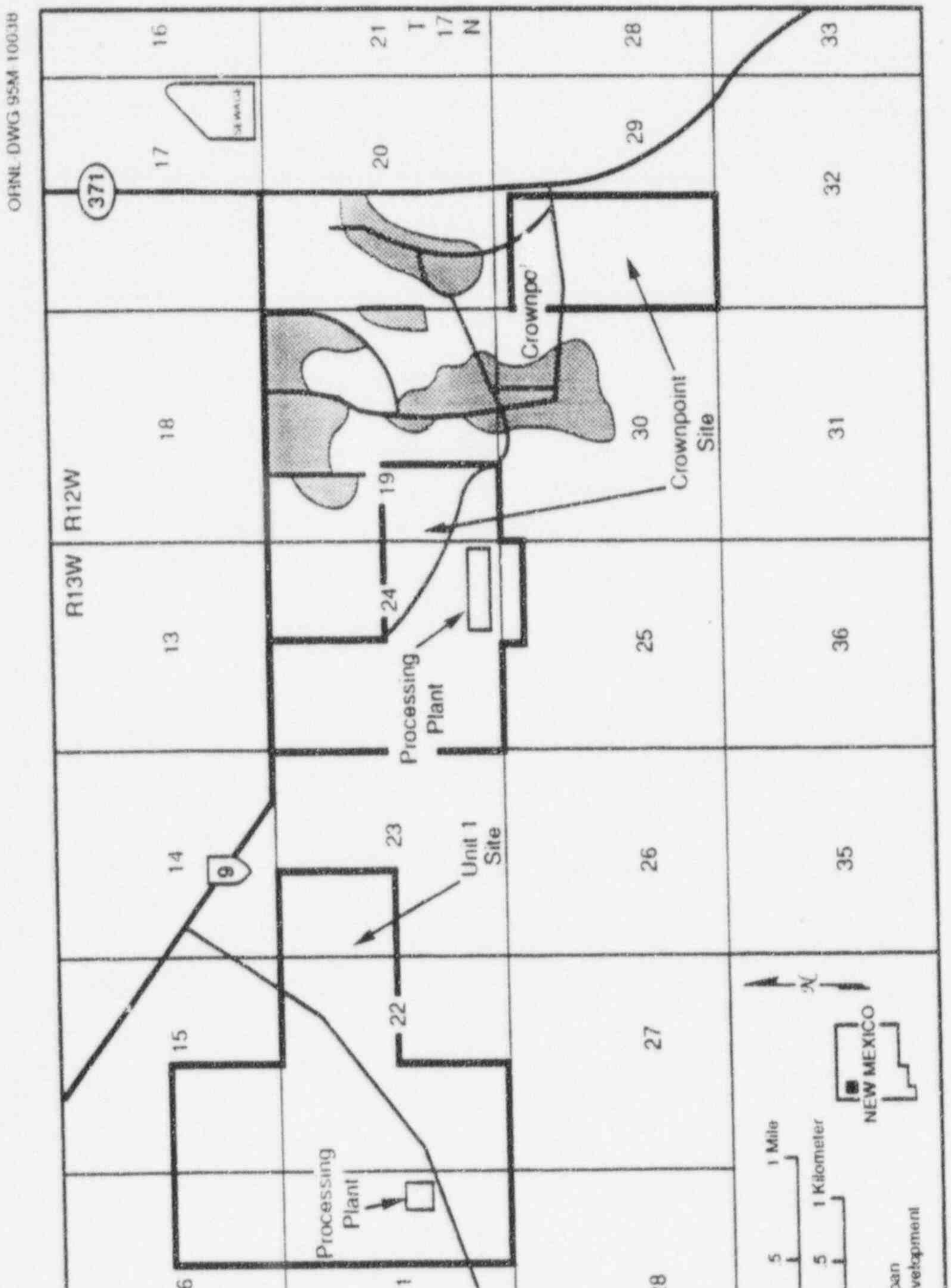

Figure 2.9. Lease area and processing plant locations for the Unit 1 and Crownpoint project sites.

2.1.4.3 The Crownpoint Site

The Crownpoint mining units and central processing facility would be located in Sections 19, 24, and 25, T17N R13W, and Section 29, T17N R12W (Figure 2.9). The Crownpoint portion of the project would use existing facilities for the central processing plant, located on the west edge of the town of Crownpoint in Section 24. HRI anticipates that uranium recovery activities at the Crownpoint site would occur over approximately 19 years.

The Crownpoint site covers 365 ha (912 acres), of which approximately 70 percent [255 ha (638 acres)] would be disturbed during project construction and operation. The estimate of 255 ha (638 acres) includes areas that have been previously disturbed as well as those that would be newly disturbed. Existing processing facilities and settling ponds, which occupy approximately 5.5 ha (14 acres) in the southeastern quarter of Section 24, would be used. Well fields would occupy approximately 205 ha (510 acres). Additional acreage would be required for access roads, on-site wastewater land application areas, and evaporation ponds. If HRI disposes of wastewater using off-site land application, it would occur in Section 12, T17N R13W. Because Section 12 would also be used for land application for the Unit 1 site under this scenario, its 256 ha (640 acres) are included above in the land disturbance calculations for Unit 1. Thus, the total land area that would be disturbed at the Crownpoint site would be approximately 255 ha (638 acres).

2.1.4.4 Site Development

Initially, HRI proposes to operate well fields only at the Church Rock site (Figure 2.10), and to transport yellowcake slurry by truck to the Crownpoint facility for drying and packaging. Mining would begin at the Unit 1 and Crownpoint sites in the late-1990s (Figure 2.11).

During initial production, HRI proposes to conduct demonstration projects at each site, producing uranium from an initial well field, and then immediately restoring the well field. These demonstrations would be intended to confirm reclamation cost data for bonding purposes.

2.2 ALTERNATIVE 2 (MODIFIED ACTION)

Under Alternative 2, the NRC would issue HRI a license for the construction and operation of a modified version of the proposed project (Section 2.1). The modified project could consist of alternatives to the proposed project in three primary areas: sites for ISL mining, sites for yellowcake drying and packaging, and liquid waste disposal methods.

2.2.1 Alternative Sites for ISL Mining

HRI proposes to conduct ISL mining at the Church Rock, Unit 1, and Crownpoint sites. However, potential impacts to public health and safety or the environment might indicate that ISL mining should not be conducted at all three sites. Alternative sites for ISL mining include:

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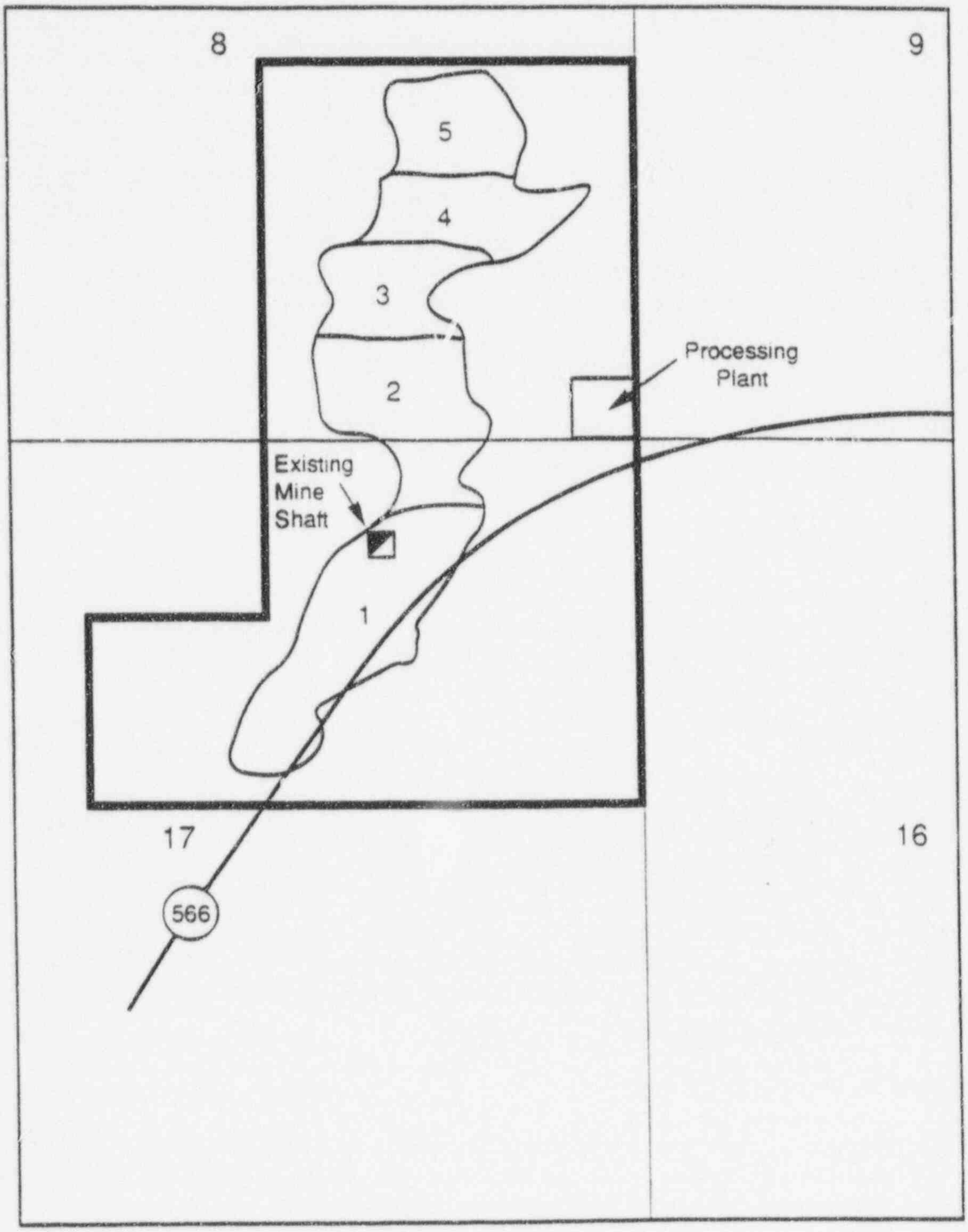

Figure 2.10. Church Rock lease area, showing mine-unit and facility locations.

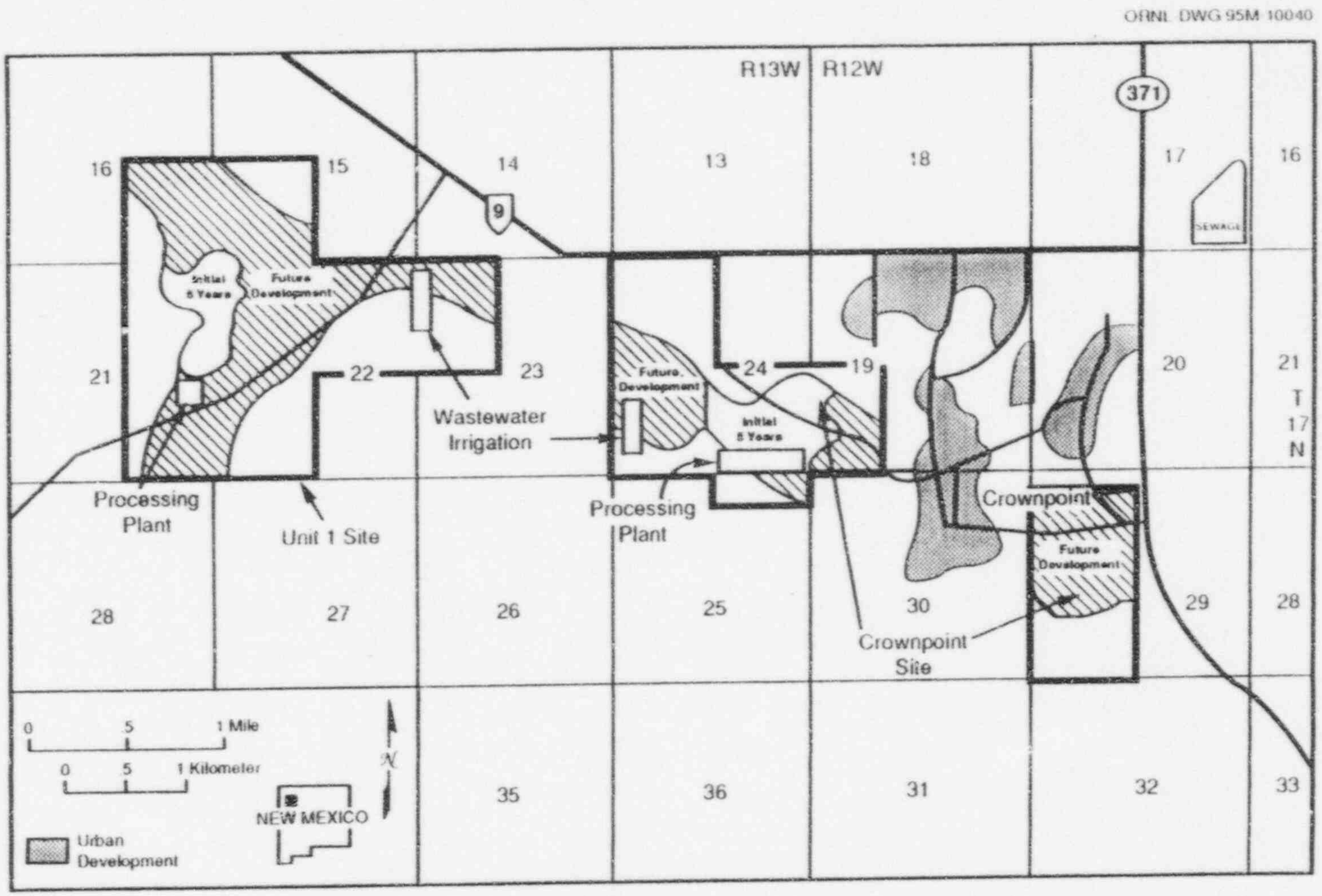

Figure 2.11. Unit 1 and Crownpoint lease areas, showing the ore zones, initial 5-year mine plan and facility locations.

- the Church Rock site only
- the Unit 1 site only
- the Crownpoint site only
- the Church Rock and Unit 1 sites only
- the Church Rock and Crownpoint sites only
- the Unit 1 and Crownpoint sites only

The primary difference between these alternatives and the proposed project is that ISL mining would occur at only one or two of the proposed sites. Thus, the potential environmental impacts of mining at the sites listed above will be addressed as subunits of the proposed project in the FEIS.

2.2.2 Alternative Sites for Yellowcake Drying and Packaging

HRI proposes to dry and package all yellowcake produced by the project at the central processing facility at Crownpoint. Alternative sites that could be selected for yellowcake drying and packaging include:

- the proposed Church Rock processing facility
- the proposed Unit 1 processing facility
- HRI's existing ISL facility at Kingsville, Texas
- the Ambrosia Lake uranium mill, located north of Milan, New Mexico (Figure 1.1)

The primary difference between these alternatives and the proposed project is that yellowcake slurry would be transported by truck to a location other than the Crownpoint processing facility. The FEIS examines the potential environmental impacts of these alternatives for drying and packaging.

2.2.3 Alternative Liquid Waste Disposal Methods

HRI's proposal for disposing of liquid wastes generated by the project is described in Section 2.1.2.4. Generally, HRI proposes to dispose of liquid wastes through a combination of evaporation ponds, aquifer reinjection, land application, and reinjection into the Westwater Canyon sandstone outside the mining area. The FEIS examines the impacts of HRI's proposal and alternative liquid waste disposal methods, including various combinations of evaporation ponds, deep-well injection, land application, and surface discharge.

2.3 ALTERNATIVE 3 (NO ACTION)

No action means that "the proposed activity would not take place, and the resulting environmental effects from taking no action would be compared with the effects of permitting the proposed activity or an alternative activity to go forward" (*Fed. Regis. 46, 18026*). Thus, the no action alternative for NRC is to not issue HRI a license for the construction and operation of facilities for ISL uranium mining and processing at the Church Rock, Unit 1, or Crownpoint sites. The no action alternative for the BLM and BIA is to not approve HRI's application for minerals operating rights and leases on the federal and Indian lands involved in the proposed project.

3. AFFECTED ENVIRONMENT

3.1 METEOROLOGY, AIR QUALITY, AND NOISE

This section describes meteorology, air quality, and noise in the region in which the three project sites are located. The description is not site-specific because the available data are collected on a regional basis and because the project sites have similar characteristics.

3.1.1 Meteorology

The project sites are located in the Northwestern Plateau climatological subdivision of New Mexico. Due to the relatively weak synoptic scale, meteorological influence in the project area is largely influenced by local topography. The region is semi-arid continental, with the mean annual precipitation averaging 26 cm (10.2 in) (TVA 1979). Precipitation typically is concentrated during summer and early fall, occurring as thundershowers of short duration. Approximately 50 percent of the precipitation falls in July through October. The mean monthly rainfall during the remainder of the year totals only 1.4 cm (0.5 in).

Temperatures in the region are represented by data from the nearby Crownpoint station, measured over a 42-year period. Table 3-1 presents mean monthly and annual normal temperatures for Crownpoint. Because of the relatively high elevation of the project area, temperatures greater than 32°C (90°F) occur infrequently, only 12 times per year on average. The extreme maximum temperature recorded at Crownpoint is 36°C (97°F). Because of the high elevation and relatively infrequent cloud cover in the project area, radiant cooling is substantial, and results in an average of 143 days of the year with temperatures below freezing. Extremely low temperatures are rare, with the lowest on record being -27°C (-17 °F).

The mean annual temperature is 10.6°C (51°F). The coldest monthly mean of -1°C (30°F) occurs in January, and the highest monthly mean of 22.2°C (72°F) occurs in July. The frost-free growing season lasts 140 days, extending from early May to early October. The mean freeze-free period lasts about 22 days longer than the growing season. However, large variations in the freeze dates occur from year to year.

Maximum precipitation occurs during the summer thunderstorm season. Table 3-2 presents normal monthly and annual precipitation for Crownpoint. The data indicate that approximately one-half of the annual precipitation total falls during July, August, and September. Most of the winter precipitation occurs as snow. Based on mean snowfall estimates for nearby locations, including Crownpoint, and on actual 1975 snowfall amounts for Gallup and Chaco Canyon National Monument, the estimated yearly average snowfall for the project area is 66 cm (26 in).

Average annual relative humidity is estimated to range from a maximum of near 65 percent about sunrise to near 30 percent in mid-afternoon. Afternoon humidity in the warmer months, however, is commonly below 20 percent. The mean annual relative humidity for Gallup is 50 percent. The gross annual lake evaporation in the project area is approximately 218 cm (86 in).

Table 3-1. Mean temperature in degrees Centigrade (Fahrenheit) for Crownpoint, New Mexico, 1931–1960

Month	Mean	Mean maximum	Mean minimum
January	-1.1 (30)	5.0 (41)	-7.8 (18)
February	2.2 (36)	8.3 (47)	-4.4 (24)
March	5.0 (41)	12.2 (54)	-2.2 (28)
April	9.4 (49)	17.2 (63)	1.7 (35)
May	14.4 (58)	22.2 (72)	6.7 (44)
June	20.0 (68)	27.8 (82)	12.2 (54)
July	22.2 (72)	29.4 (85)	15.0 (59)
August	21.1 (70)	28.3 (83)	13.9 (57)
September	17.8 (64)	25.0 (77)	10.0 (50)
October	11.7 (53)	18.9 (66)	4.4 (40)
November	4.4 (40	11.7 (53)	-2.2 (28)
December	0.0 (32)	6.7 (44)	-6.1 (21)
Annual	10.6 (51)	17.8 (64)	3.3 (38)

Source: TVA 1979.

Table 3-2. Monthly and annual precipitation for Crownpoint, New Mexico, 1931–1960

Month	Millimeters	Inches
January	14.7	0.58
February	14.5	0.57
March	11.9	0.47
April	12.7	0.50
May	16.8	0.66
June	17.3	0.68
July	43.7	1.72
August	53.6	2.11
September	27.9	1.10
October	20.8	0.82
November	12.2	0.48
December	13.5	0.53
Annual	259.6	10.22

Source: TVA 1979.

Little comprehensive wind observation data are available for the immediate project area. The nearest National Weather Service (NWS) station with available wind data is Gallup (TVA 1979), located approximately 19 km (12 miles) and 56 km (35 miles) west south west of Church Rock and Crownpoint, respectively. Five-year wind data for Gallup (U.S. Department of Commerce 1981) indicate a prevailing wind with southwest and west-southwest components (Figure 3-1). A windy season occurs during the spring months, averaging 19 km/hr (12 mph), and summer wind averages 13 km/hr (8 mph). Winds are generally calm 10 percent of any 24-hour period, and exceed 38 km/hr (24 mph) 5 percent of the time.

Based on the input parameters of solar altitude, cloud cover, ceiling height, and wind speed, atmospheric stability can be classified into several categories (TVA 1979). The closest weather stations with available long-term atmospheric records from which stability conditions can be estimated are Zuni, Farmington, and Albuquerque, New Mexico, about 90 km (57 mi) southwest, 115 km (72 mi) north, and 150 km (93 mi) southeast of the Crownpoint site, respectively. The frequencies of the various stability conditions for these three locations are presented in Table 3-3. The data indicate that stability conditions contributing to good dispersion conditions (Pasquill Classes A through D) occur more than 55 percent of the time at all three stations.

Thunderstorms are relatively frequent during the summer months in northwestern New Mexico, and occur on about 50 days per year in the project area. Tornadoes are occasionally reported in New Mexico, most frequently during afternoon thunderstorms from May through August, and typically in the eastern part of the state. Only one tornado was reported in the one-degree square including Crownpoint during the period from 1955 to 1967. The resulting calculated probability of a tornado striking the site in any year is 0.00006, or once in each 16,700 years.

Maximum short-duration rainfalls in this area are generally caused by thunderstorms, while maximum precipitation of longer duration results from the infrequent invasion of a tropical cyclone from the Gulf of Mexico or the Gulf of California. Occasionally, brief, high-intensity showers may cause flash floods in the normally dry arroyos. Information regarding potential flooding is discussed in Section 3.3.2.

3.1.2 Air Quality

National Ambient Air Quality Standards (NAAQS) exist for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), lead (Pb), and particulate matter small enough to move easily into the lower respiratory tract (particles less than 10 μm in aerodynamic diameter, designated PM-10). The NAAQS are expressed as pollutant concentrations that are not to be exceeded in the ambient air; that is, in the outdoor air to which the general public has access [40 CFR 50.1(e)]. Primary NAAQS are designated to protect human health; secondary NAAQS are designated to protect human welfare by safeguarding environmental resources (such as soils, water, plants, and animals) and manufactured materials. Primary and secondary NAAQS are presented in Table 3-4. New Mexico has adopted the NAAQS as the air quality standards for the state.

The air quality in the project region is good. The area is sparsely populated, and is not heavily developed with industrial sources of air pollution. The area is designated as being in attainment of the all the individual NAAQS (EPA 1996).

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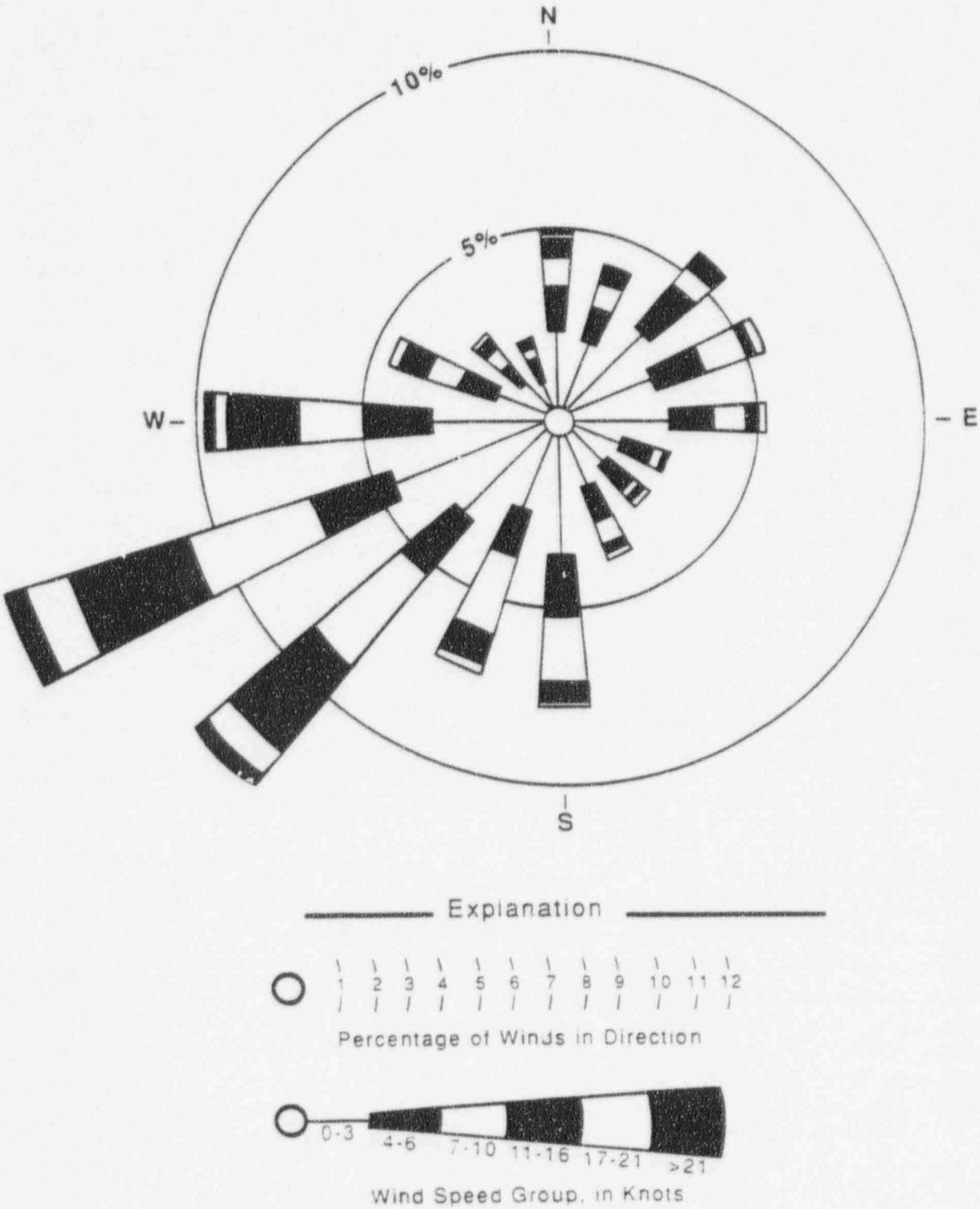

Figure 3-1. Wind rose for Gallup, New Mexico—average annual conditions, 1976–1980.
Source: U.S. Department of Commerce 1981.

Table 3-3. Percent frequency distributions of Pasquill Stability Classes for Zuni, Farmington, and Albuquerque

Stability class	Zuni (1967–1971)	Farmington (1960–1968)	Albuquerque (1960–1964)
A (extremely unstable)	2.4	4.8	2.4
B (unstable)	7.0	10.6	13.5
C (slightly unstable)	14.2	12.4	12.8
D (neutral)	35.1	27.8	30.0
E (slightly unstable)	17.8	10.7	13.8
F (stable)	23.5	34.4	27.5

Source: TVA 1979.

Table 3-4. National Ambient Air Quality Standards[a]

	NAAQS (fg/m^3)		
Pollutant	Primary	Secondary	Measurement
Carbon monoxide (CO)	10,000 40,000		8-hr average[b] 1-hr average[b]
Nitrogen dioxide (NO_2)	100	100	Annual arithmetic mean
Ozone (O_3)	235	235	1-hr average[c]
Lead (Pb)	1.5	1.5	Quarterly average[d]
Particulate <10 microns diameter (PM-10)	50 150	50 150	Annual arithmetic mean 24-hr average[c]
Sulfur dioxide (SO_2)	80 365	1300	Annual arithmetic mean 24-hr average[b]

[a]Where no value is listed, there is no corresponding standard.
[b]Not to be exceeded more than once per year.
[c]Not to be exceeded on more than 1 day/year on the average over 3 years.
[d]Calendar quarter.

Source: EPA 1996.

In addition to ambient air quality standards, which represent an upper bound on allowable pollutant concentrations, there are national standards for the prevention of significant deterioration (PSD) of air quality (40 CFR 51.166). The PSD standards differ from the NAAQS in that the NAAQS provide maximum allowable concentrations of pollutants, while PSD requirements provide maximum allowable increases in concentrations of pollutants for areas already in compliance with the NAAQS. PSD standards are therefore expressed as allowable increments in the atmospheric concentrations of specific pollutants. Allowable PSD increments currently exist for three pollutants: NO_2, SO_2, and PM-10. PSD increments are particularly relevant when a major proposed action (involving either a new source or a major modification to an existing source) may degrade air quality without exceeding the NAAQS, as would be the case, for example, in an area where the ambient air is very clean. One set of allowable increments exists for Class II areas, which cover most of the United States, and a much more stringent set of allowable increments exist for Class I areas, which are specifically designated areas where the degradation of ambient air quality is to be severely restricted. Class I areas include certain national parks and monuments, wilderness areas, and other areas as described in 40 CFR 51.166(e) and 40 CFR 81:400–437. Maximum allowable PSD increments for Class I and Class II areas are given in Table 3-5. Class I areas in the Four Corners region include Mesa Verde National Park and Arches National Park. A list of Class I areas in Arizona, Colorado, New Mexico, and Utah is presented in Table 3-6.

Table 3-5. Allowable increments for Prevention of Significant Deterioration of air quality (allowable PSD increments)[a]

Pollutant	Allowable PSD increments (fg/m^3) Class I	Class II	Measurement
Carbon monoxide (CO)			
Nitrogen dioxide (NO_2)	2.5	25	Annual average
Ozone (O_3)			
Lead (Pb)			
PM-10[b]	4	17	Annual average
	8	30	24-hr[c]
Sulfur dioxide (SO^2)	2	20	Annual average
	5	91	24-hr[d]
	25	512	3-hr[d]

[a]Where no value is listed, there is no corresponding standard. Class I areas are specifically designated areas in which degradation of air quality is severely restricted (e.g., many national parks); Class II areas (all areas in the United States not designated Class I) have a less stringent set of allowable PSD increments.

[b]Particulate matter less than 10 µm in diameters.

[c]Not to be exceeded on more than 1 day/year on the average over 3 years.

[d]Not to be exceeded more than once per year.

Table 3-6. EPA Class I Prevention of Significant Deterioration areas

Utah	Colorado
Arches National Park	Black Canyon of the Gunnison Wilderness
Bryce Canyon National Park	Eagles Nest Wilderness
Canyonlands National Park	Flat Tops Wilderness
Capitol Reef National Park	Great Sand Dunes Wilderness
Zion National Park	La Garita Wilderness
	Maroon Bells-Snowmass Wilderness
Arizona	Mesa Verde National park
	Mount Zirkel Wilderness
Chiricahua National Monument Wilderness	Rawah Wilderness
Chiricahua Wilderness	Rocky Mountain National Park
Galiuro Wilderness	Weminuche Wilderness
Grand Canyon National Park	West Elk Wilderness
Mazatzal Wilderness	
Mount Baldy Wilderness	**New Mexico**
Petrified Forest National Park	
Pine Mountain Wilderness	Bandelier Wilderness
Saguaro Wilderness	Bosque del Apache Wilderness
Sierra Ancha Wilderness	Carlsbad Caverns National Park
Superstition Wilderness	Gila Wilderness
Sycamore Canyon Wilderness	Pecos Wilderness
	Salt Creek Wilderness
	San Pedro Parks Wilderness
	Wheeler Peak Wilderness
	White Mountain Wilderness

Source: EPA 1994.

3.1.3 Noise

Background noise around the three project sites is mostly from light automobile and truck traffic, and would be comparable to noise levels in a quiet residential area. This is about 50 decibels in the normal (A-scale) auditory frequency band [dB(A)]. Residents (i.e., potentially sensitive receptors) are adjacent to or within close proximity of (less than 1 km) all three project sites.

3.2 GEOLOGY AND SOILS

3.2.1 Regional

Topographic relief in the vicinity of the project sites is approximately 600 m (2,000 ft), from an elevation of 2,000 m (6,500 ft) to 2,600 m (8,500 ft). The region is characterized by mesas that dip gently to the

north and by broad valleys with intermittent streams. Locally, arroyos have incised the mesas by headward erosion forming steep-sided canyons.

The project sites are located northeast of the Zuni Uplift on the Chaco Slope structural subdivision of the San Juan Basin (Figure 3-2). The San Juan Basin is a structural depression occupying a major portion of the southeastern Colorado Plateau physiographic province (Hunt 1974). The plateau encompasses much of western Colorado, eastern Utah, northeastern Arizona, and northwestern New Mexico. The San Juan Basin is underlain by up to 3,000 m (10,000 ft) of sedimentary strata, which generally dip gently from the margins toward the center of the basin. The margins of the basin are characterized by relatively small elongate domes, uplifts, and synclinal depressions.

The stratigraphic sequence in the San Juan Basin is composed of units ranging from Precambrian to Holocene age. Stratigraphic descriptions presented here are limited to formations that would be involved in the proposed mining operation, or formations that may have environmental significance, such as important aquifers found above and below the mine zone. A generalized stratigraphic column is shown in Figure 3-3.

The Morrison Formation is composed of the Recapture, Westwater Canyon, and Brushy Basin Members and is the host formation for major uranium deposits in the area. In addition, the Westwater Canyon is an important regional aquifer. The following regional descriptions are derived from reports by Green and Pierson (1977), Hilpert (1963; 1969), TVA (1979), Chenoweth and Learned (1980), and HRI's Environmental Report.

The Recapture Member is the bottom most member of the Morrison Formation. It is as thick as 150 m (500 ft) northwest of Gallup, but thins considerably and, in outcrops near Gallup and eastward, is only 45 to 90 m (150–300 ft) thick. The Recapture is regarded as one of the most variable stratigraphic units in the area. It occurs in the Gallup mining district as a sequence of interbedded siltstone, mudstone, and sandstone strata. Individual strata range from centimeters to meters in thickness. Sandstone beds are generally less than 5 m (15 ft) thick (Hilpert 1969). The Recapture is widely believed to interfinger with the underlying Cow Springs Sandstone, and several authors have combined the two units as one. No significant uranium deposits occur in the Recapture Member.

The Westwater Canyon Member of the Morrison Formation consists of interbedded fluvial red, tan, and light gray arkosic sandstone, claystone, and mudstone. It is the major water-bearing member of the Morrison. The unit's thickness in outcrop from Gallup to the continental divide ranges between 53 and 85 meters (175 and 275 ft) (Hilpert 1969) and is known to be considerably thicker locally. In most places, the Westwater displays one or more mudstone units that range from thin partings to units up to 6 m (20 ft) thick. These mudstones have limited lateral continuity, and only the thicker ones are extensive. This member is host for the major uranium deposits in the region. The uranium occurs in coarse-grained, poorly sorted sandstone units, and is closely associated with the carbonaceous material that coats the sand grains.

The Brushy Basin Member overlies the Westwater Canyon, and ranges from 12 to 40 m (40 to 125 ft) thick in the Gallup region. It is mainly composed of light greenish gray and varicolored claystone, interbedded with sandstone lenses having similar lithology and appearance to sandstones found in the Westwater Canyon Member (Ristorcelli 1980). The mudstones are largely derived from volcanic ash falls (Peterson 1980) and contain considerable amounts of bentonite. Its contact with the Westwater Canyon is gradational and interfingering.

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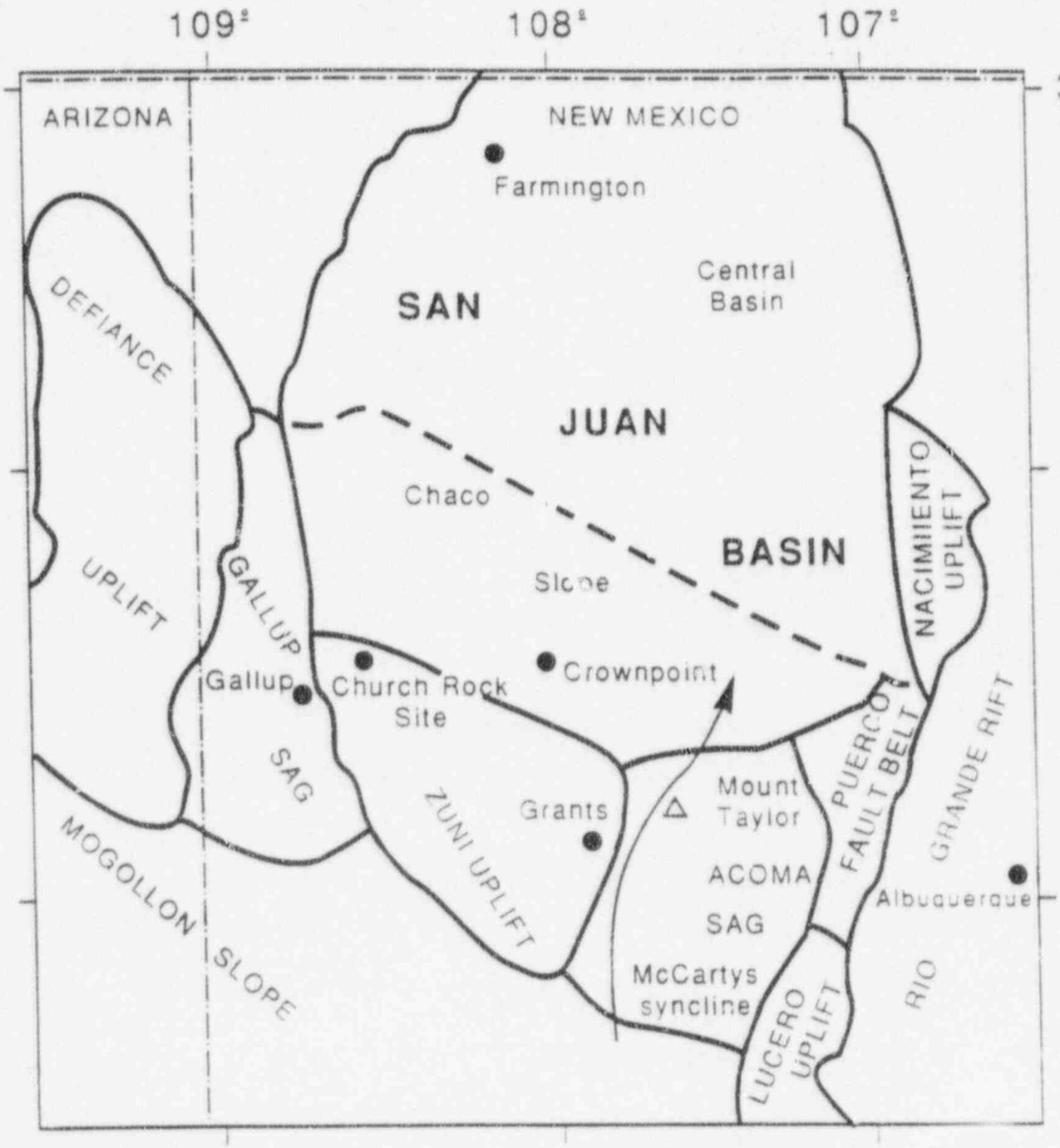

Figure 3-2. Structural setting of the San Juan Basin. *Source*: Kelly 1963; Kelly and Clinton 1960.

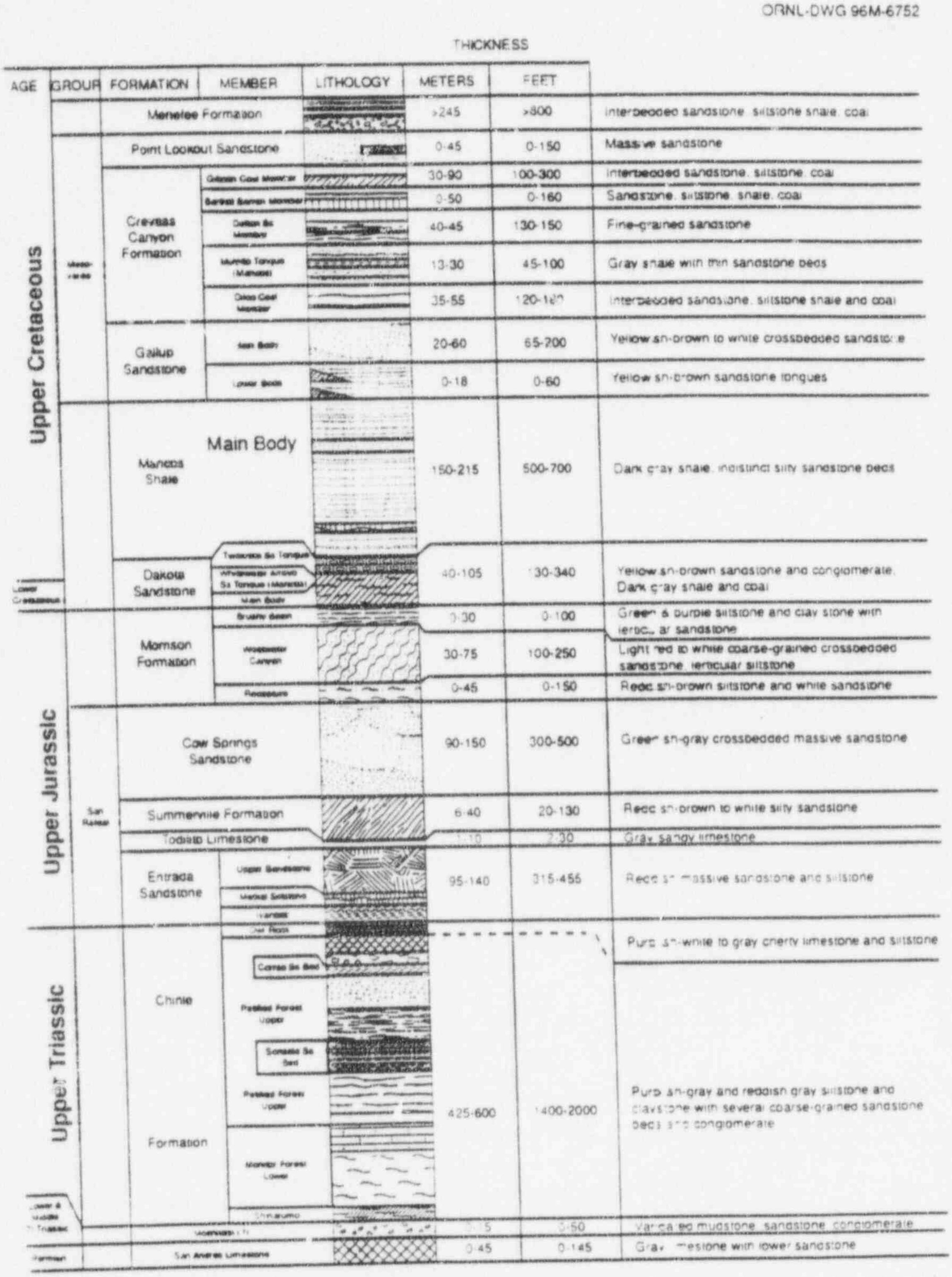

Figure 3-3. Stratigraphic column of the Church Rock, New Mexico area. *Source:* adapted from Chenoweth and Learned 1980.

The Dakota Sandstone is the basal formation of the Cretaceous System and unconformably overlies the Morrison Formation. The Dakota is a gray-brown quartz sandstone with some interbedded conglomerate, shale, carbonaceous shale, and coal. It is a marine sandstone and is considered to represent the earliest transgression of Late Cretaceous seas. The Dakota crops out around the margins of the San Juan Basin and thickens towards the center of the basin to about 60 m (200 ft) regionally.

The Mancos Shale overlies the Dakota Sandstone and is a thick, mostly uniform gray marine shale containing thin lenses of fine-grained sandstone. It varies in thickness up to 600 m (2,000 ft) regionally. The Mancos has two upper sandy tongues, the Mulatto and Satan, that intertongue with the Mesaverde Group and merge with the main body of the Mancos to the east. The unit's lower shale tongues interfinger with the underlying Dakota. The Mancos forms the foundation bedrock at the Church Rock site.

The Mesaverde Group overlies the Mancos Shale and is composed of several formations that are described below in ascending order:

1. The Gallup Sandstone forms the basal unit of the Mesaverde Group. It is a gray-white or pink-to-tan, medium to fine-grained, moderately well-sorted, calcareous, cross-bedded sandstone. Unlike the main body of the Gallup Sandstone, the Torrivio Sandstone Member, which intertongues with the Crevasse Canyon Formation, is very coarse- to medium-grained, poorly-sorted cross-bedded fluvial sandstone. The thickness of the Gallup varies regionally from 0 to more than 70 m (230 ft) and is about 25 m (80 ft) thick near Crownpoint.
2. The Crevasse Canyon Formation overlies the Gallup Sandstone and varies in thickness from 150 to more than 230 m (490 to 750 ft). It consists of an upper and lower member comprised of interbedded lenticular sandstones, claystones, and thin discontinuous coal beds separated by a sheet-like body of fine-grained, well-sorted calcareous marine sandstone. In ascending order, the Dilco Coal Member, the Dalton Sandstone Member, and the Gibson Coal Member, make up the Crevasse Canyon Formation.
3. The Point Lookout Sandstone overlies the Crevasse Canyon Formation and is split into two parts, the lower Hosta Tongue and the upper main body, by the Satan Tongue of the Mancos Shale. The Point Lookout is a fine to medium-grained, grayish-brown to white sandstone. The Satan Tongue of the Mancos Shale consists of interbedded shale, mudstone, and thin calcarious sandstone beds.

Thick colluvium deposits are commonly found forming a mantle on steep slopes surrounding sandstone mesas and cuestas. By contrast, Quaternary alluvium is found on the valley floors of the region. These deposits consist of fine sand, silt, and clay derived from the weathering of sandstone, siltstone, and mudstone exposed at the surface. Alluvial deposits generally are thin, but are known to exceed a thickness of 10 m (30 ft) in larger valleys.

The Grants Uranium Belt is one of the largest producers of uranium in the world. From 1950 through 1978, ore containing 123,000 metric tons of uranium oxide were extracted (Chenoweth and Holen 1980). This represented 40 percent of United States production. Most uranium mineralization in the region occurs as pore fillings or coatings in sandstone of the Morrison Formation, and less importantly in the Dakota Sandstone and Todilto Limestone (Hilpert 1963). The ore bodies occur as elongated masses or roll-front deposits. Generally, the deposits are a few feet thick and several hundred to a thousand feet long and may be stacked, usually parallel to the strike of the host rock. The major mineral is coffenite with minor amounts of uraninite, andersonite, bayleyite, uranophane, tyuyamunite, and carnotite present.

Uranium first migrated into sandstone relatively soon after its deposition in tuffaceous sediment and other rocks of volcanic origin. The uranium was dissolved and transported by migrating ground water until it was precipitated as coatings on sandstone grains. Ore deposits are associated with well-developed channel sandstones in the upper three-fourths of the Westwater Canyon Member. Ore zones are irregular in configuration and elongated parallel to depositional features (N35°W). Varying rates of groundwater flow controlled by sedimentary facies in each stratigraphic zone in the Westwater Canyon produced stacked ore deposits near one another, but not necessarily vertically above and below one another (Peterson 1980). The deposits are found as irregular pods, or as the classic c-shape roll fronts (Figure 3-4).

Site-specific information for this FEIS was derived by interpreting geophysical log information submitted by HRI, and to the extent practical, by verifying the information with independently published accounts.

3.2.2 Crownpoint

Figure 3-5 contains a stratigraphic column for the Unit 1 and Crownpoint sites. HRI's submittals show that the Recapture mudstone unit underlying the Crownpoint site is generally about 75 m (250 ft) thick. Wentworth and others (1980) verify that the Recapture Member underlying the east side of Crownpoint is about 80 m (260 ft) thick below the Section 29 uranium deposits. In the Crownpoint area, the top of the Westwater Canyon is found at an average approximate elevation of 1525 m (5000 ft), or a depth of 560 m (1840 ft). HRI's log data indicate that the Westwater Canyon Member thickens from about 72 m (236 ft) in the western part of Unit 1, to 90 m (295 ft) in Section 24, to over 105 m (345 ft) in Section 19 north of Crownpoint. Wentworth and others (1980) report similar thickness variance east of Crownpoint in Section 29, ranging from 76 to 107 m (250 to 350 ft). The Westwater Canyon consists of a series of gray to light red, fine- to medium-grained arkosic sandstones with a number of well-defined mudstone layers. The mudstone units are pale green or varicolored and range from a few centimeters to 9 m (30 ft) thick.

HRI's data indicate that the Brushy Basin Member averages 20 to 35 m (67 to 112 ft) thick near Crownpoint. These values agree with data from the Section 29 ore deposits (Wentworth and others 1980). The Brushy Basin member contains shale with a few thin and discontinuous sandy lenses.

Rocks in the Crownpoint area dip approximately 1 to 2 degrees north-northeast. Wentworth and others (1980) report that northeast-trending faults are known in the Crownpoint area, but they have limited displacement. Robertson (1986) maps two east-trending faults crossing the town (Figure 3-6). Field observation indicates that one of the faults is well exposed on the mesa slopes in the southwest quarter of Section 19. The fault is observed in outcrops where sandstone and coal strata in the northern block are offset relatively downward by approximately 7 m (23 ft). Robertson's (1986) interpretation reveals that the fault steepens in the subsurface, passing through the ore zone. Associated cross-sections indicate that the offset of this fault is minor compared to strata thickness, and indicate that differing sandstone units are not juxtaposed.

Uranium deposits at the Crownpoint site average nearly 4 m (11 ft) thick in each zone (USGS 1982). The stacked ore zones have a combined thickness of about 37 m (120 ft). The combined dimensions of the Unit 1 and Crownpoint ore bodies exceed 8 km (5 mi) long, and their width varies from 290 to 760 m (950 to 2500 ft).

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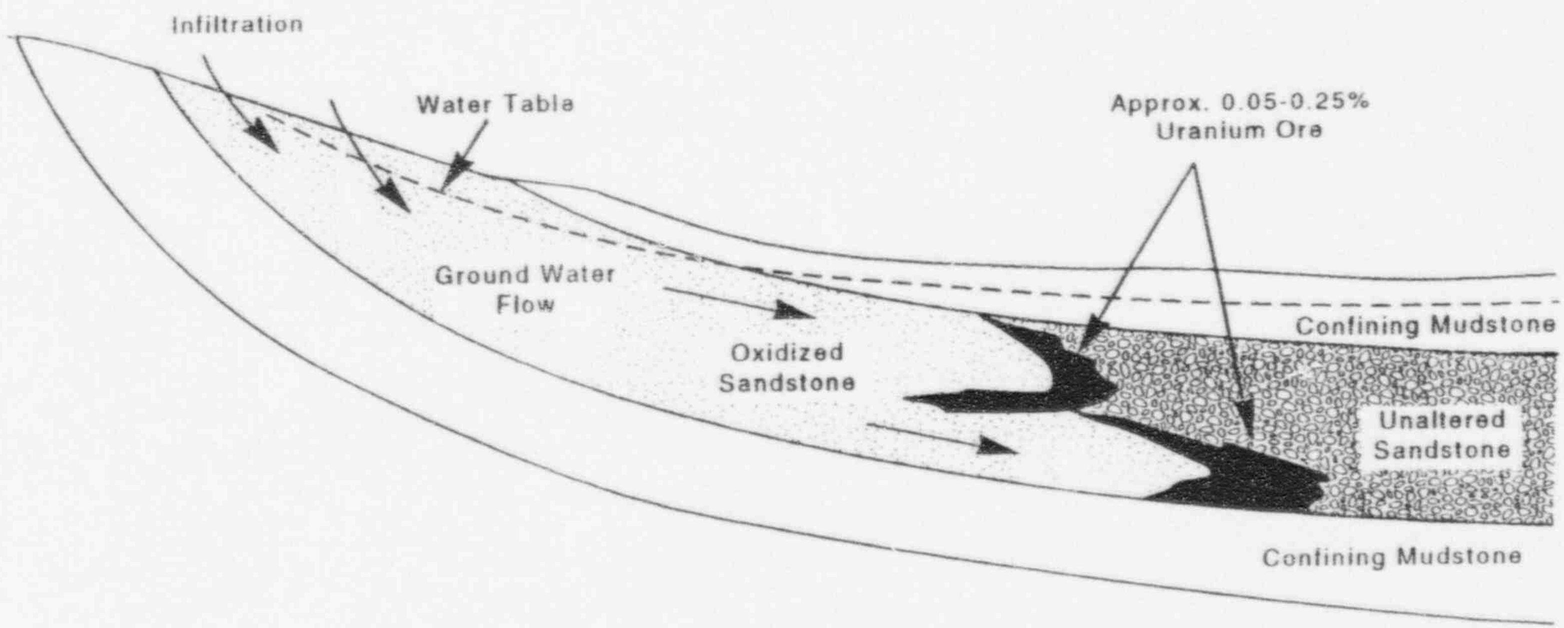

Figure 3-4. Simplified cross-section of roll-front uranium deposits formed by regional groundwater migration.

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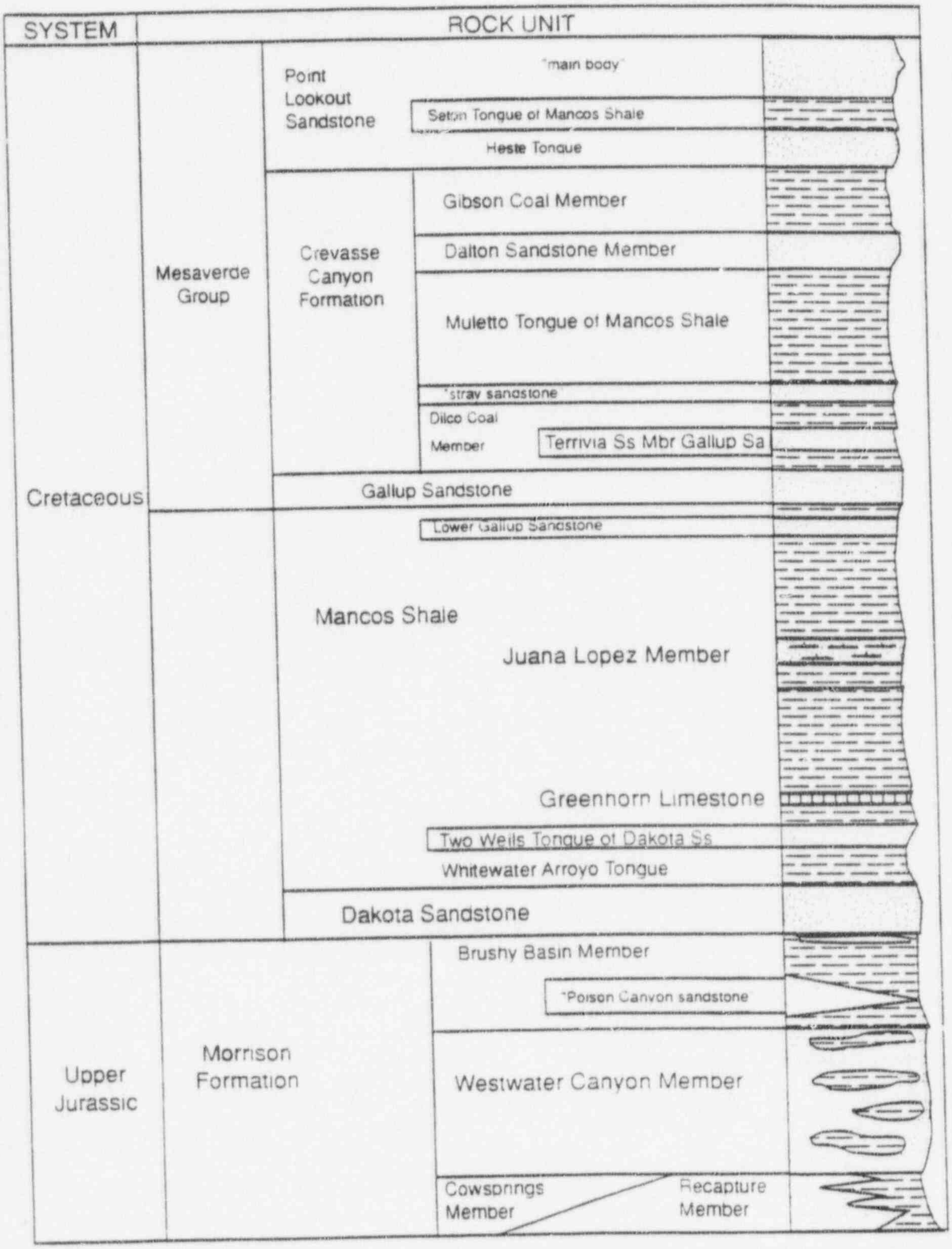

Figure 3-5. Stratigraphic column of the Unit 1 and Crownpoint Sites.

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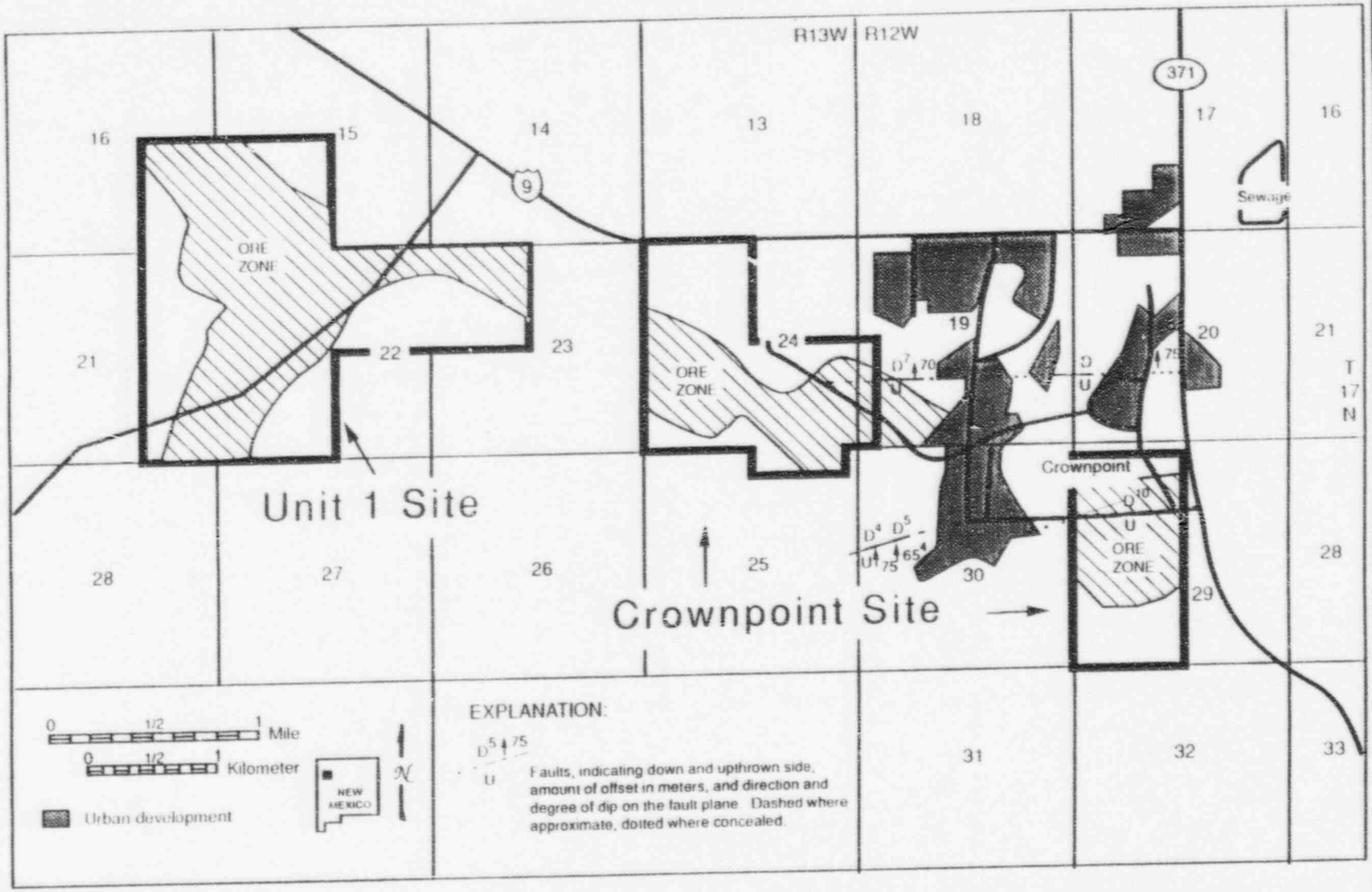

Figure 3-6. Surface locations of faults and ore zones in the Crownpoint area.

Major soil associations in the Crownpoint area are the Lohmiller-San Mateo, Hagerman-Travessilla, and Rock Land-Travessilla (TVA 1979). The Lohmiller-San Mateo association occupies the lowest topographic position in the area (Table 3-7). It occurs on flood plains, terraces, and gently sloping plains along ephemeral streams. Because the association is formed on alluvium derived from sandstone and shale, the soils are 15 to 25 cm (6 to 10 in) thick, light brownish-gray to pale brown, calcareous clay loam to loam. They form a surface layer overlying 152 cm (60 in) or more of stratified, fine-textured alluvium.

Table 3-7. Selected characteristics of the Lohmiller-San Mateo Soil Association in the Crownpoint area

Property	Description
Topographic position	Flood plains and low terraces
Texture	Loam or clay loam
Slope	0 to 3 percent
Shrink-swell potential	Moderate-high
Permeability	0.2–0.6 inches per hour

Source: TVA 1979.

The dominant Hagerman and Travessilla soils of the Hagerman-Travessilla association are not as closely related as the two major soil types of the Lohmiller-San Mateo association. Hagerman soil (Table 3-8), a noncalcareous fine sandy loam to loam, is confined to the mesa and ridge tops, whereas the thinner Travessilla soil (Table 3-9) occurs on steeper slopes of the mesas, ridges, and breaks. The surface layer has a fine sandy loam texture and is slightly calcareous. Small angular sandstone fragments are characteristic of the surface layer and increase in number with depth. Both soils are generally light brown in color.

Table 3-8. Selected characteristics of the Hagerman soils in the Crownpoint area

Property	Description
Topographic position	Mesa and ridge tops
Texture	Fine sandy loam to loam
Slope	1 to 5 percent
Shrink-swell potential	Low to moderate
Permeability	0.6–2.0 inches per hour

Source: TVA 1979.

Table 3-9. Selected characteristics of the Travessilla Soils in the Crownpoint area

Property	Description
Topographic position	Steep slopes
Texture	Fine sandy loam with rock fragments
Slope	3 to 25 percent
Shrink-swell potential	Low
Permeability	2–6 inches per hour

Source: TVA 1979.

The Rock Land-Travessilla soil association occurs in rough, broken topography with considerable variation in local relief. Outcrops of sandstone and shale are common on the steep canyon walls and escarpments, with thin deposits of gravelly alluvium occurring on the breaks adjacent to larger drainages. This association dominantly consists of a complex of shallow soils and outcrops of sandstone and other sedimentary rocks. However, small isolated pockets of moderately deep soils do occur where topography permits.

3.2.3 Unit 1

HRI's submittals show that the Unit 1 site's geologic units and soils are very similar to the Crownpoint site's, which the exception that the Recapture mudstone unit underlying the Unit 1 and Crownpoint sites is generally about 75 m (250 ft) thick and the Brushy Basin Member averages 47 m (153 ft) thick. This similarity between the two sites is to be expected since their site boundaries are about one half mile from each other.

3.2.4 Church Rock

Figure 3-7 contains a stratigraphic column of the Church Rock site. HRI indicates that the Recapture Member is at least 45 m (150 ft) thick in the mine area, and overlies the Cow Springs Sandstone. This generally agrees with regional isopach data of Morrison strata (Saucier 1967) indicating that the Recapture is 60 m (200 ft) thick in this area. Hilpert (1969) provides cross sections through the old Church Rock mine, based on Phillips Petroleum Company drilling logs, which indicate that a tongue of Cow Springs sandstone closely underlies the Westwater Canyon. This sandstone, however, coincides with a sandstone interpreted by HRI in the lowermost part of the Westwater, and appears to be underlain by Recapture Member shale. In Section 13, west of HRI's Church Rock site, Peterson (1980) indicates that the Recapture Member does not occur, and the Westwater Canyon Member lies directly on the Cow Springs sandstone.

The top of the Westwater Canyon is found at depths ranging 140 to 230 m (460 to 760 ft), dipping north-northeastward beneath the Church Rock site (HRI 1988). HRI's drilling logs from Church Rock indicate that the Westwater Canyon Member averages 80 m (263 ft) thick in Section 17, and that the

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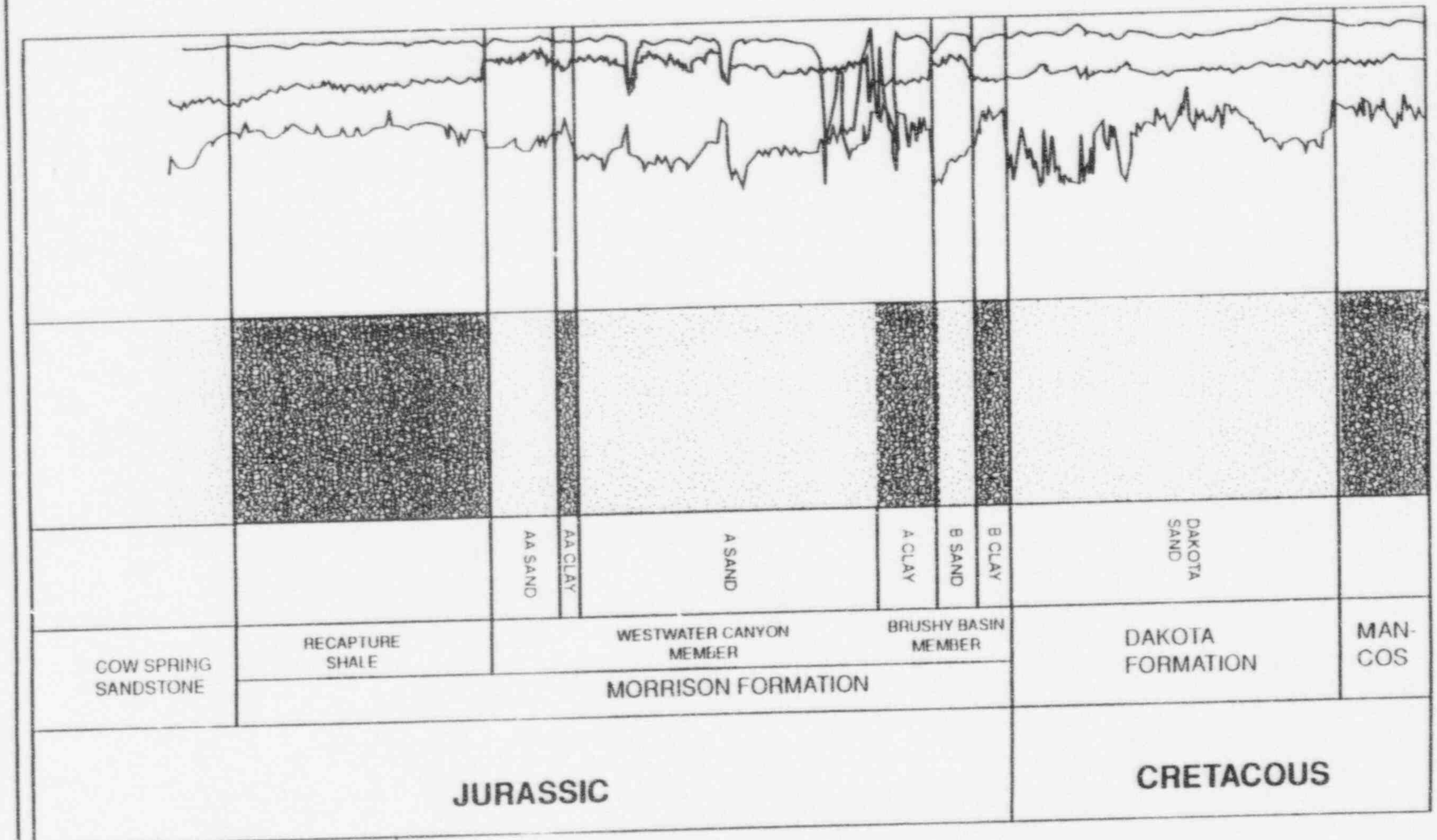

Figure 3-7. Stratigraphic column of the Church Rock Site.

Westwater is not fully penetrated by wells in Section 8. Peterson (1980) reports Westwater thickness ranges from 67 to 82 m (220 to 270 ft) 3.5 km (2 mi) west of the Church Rock site. HRI's logs from exploration drill holes and water wells indicate a relatively uniform thickness across the proposed mining area.

HRI's data indicate that the Brushy Basin Member (above the Westwater) is composed of two separate mudstone beds with an intervening sandstone layer. Data in the Environmental Report (HRI 1988) from wells along the ore body indicate that the total thickness of the unit averages 19 m (63 ft). The thickness of the lower mudstone is 5 to 10 m (16 to 32 ft), while the sandstone is 4 to 9 m (13 to 28 ft), and the upper mudstone is 5 to 10 m (16 to 33 ft). Mine-zone cross sections figured by Hilpert (1969) agree with these interpretations.

Strata in the Church Rock area display a northward dip of approximately 3 degrees. Some of the sandstone units in the area are known to exhibit jointing and fracturing in the subsurface. An account by Read and Werts (1967) indicates that the old Church Rock mine experienced excessive water seepage owing to fracture zones in the Westwater Canyon sandstones. Northeast of the mine site, Pipeline Canyon is thought to coincide with a fault. The location of the fault is approximated by Chapman and others (1974) (Figure 3-8) trending southwestward into Section 17 (HRI's proposed permit area) and within 100 m (325 ft) of HRI's monitor well ring. The amount of potential fault displacement is not estimated.

According to Peterson (1980), the Pipeline fault extends southwestward and occurs approximately 1.5 km (1 mi) southeast of the Section 13 mining property area. This interpretation places the fault outside HRI's proposed permit area. A more recent detailed geologic map (Kirk and Zech 1987) indicates that the fault does not occur at all. This geologic map indicates no offset structural contours in the area. This interpretation is repeated by several regional geological studies including Sears and others (1936), O'Sullivan and Beaumont (1957), and Cooley and others (1969). No evidence for the fault is found in any of the site drilling data, and HRI indicates that if it exists, it is probably found some distance to the east.

The Church Rock site contains mineralization in the Cretaceous Dakota Sandstone and the Westwater Canyon Member of the Jurassic Morrison Formation (USGS 1975). The proposed operations would occur in sandstone in the upper Westwater. HRI has designated the production zone within the Westwater Canyon, as the "A" sand.

Mineral resources present at the Church Rock site are contained in roll fronts and elongated tabular deposits (USGS 1975). Mineralization varies in thickness, but averages 3 m (9 ft) thick in each zone. Because the ore bodies are stacked, it has a combined thickness of about 24 m (80 ft). Overall dimension of the ore body is 1600 m (5300 ft) long and up to 300 m (1000 ft) wide.

The Church Rock lease area exhibits a complex mixture of soil associations. The well field and potential irrigation areas are underlain by two soil series, the El Rancho and Mikam (Table 3-10).

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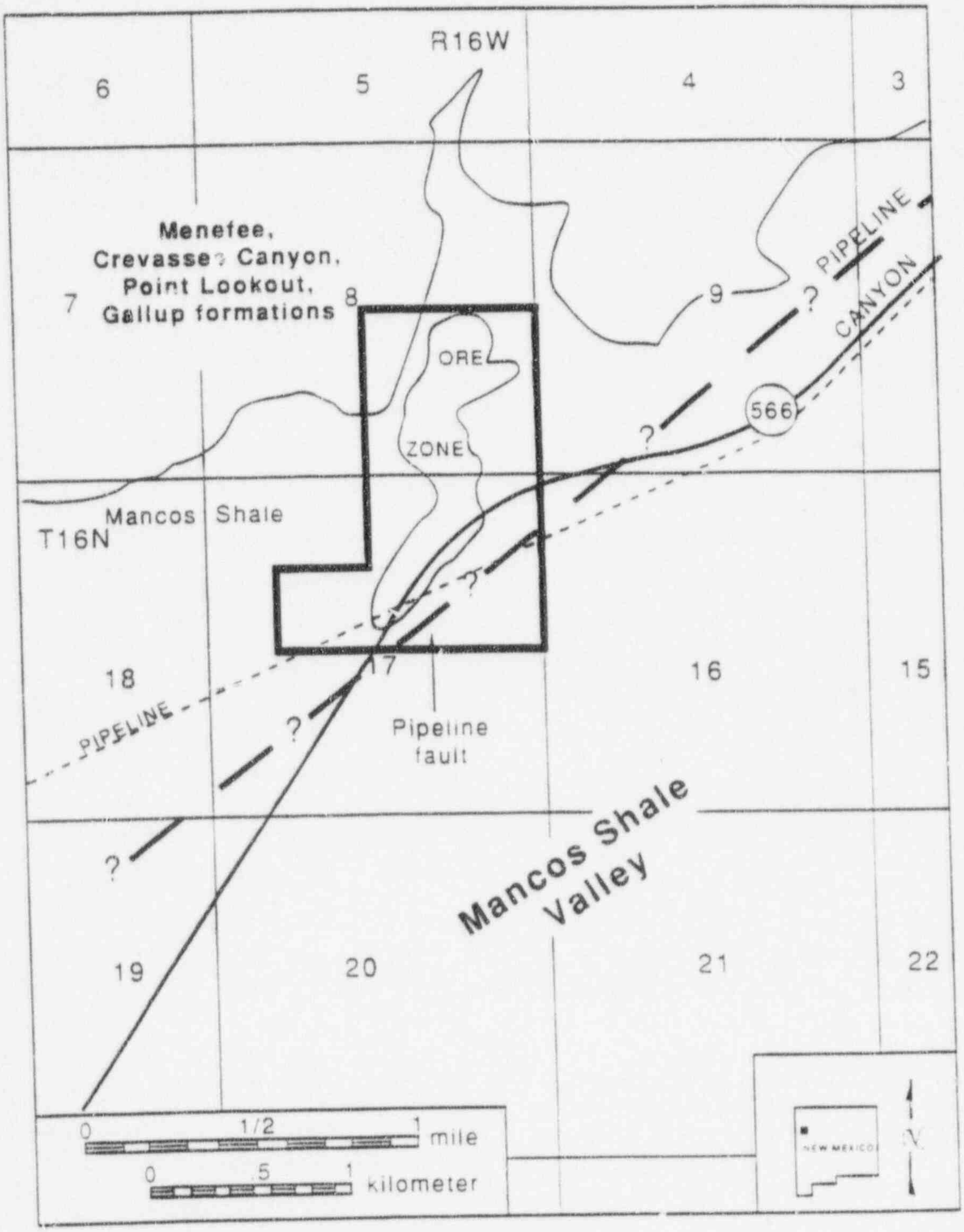

Figure 3-8. Generalized geologic map of the Church Rock Site area and the hypothetical Pipeline Fault. *Sources*: Kirk and Zech 1987; Chapman and Griswold 1979.

Table 3-10. Selected characteristics of the El Rancho and Mikam Soil Series found in the Church Rock lease area

Property	Mikam	El Rancho
Topographic position	Alluvial fans and toe slopes	Terraces and valley bottoms
Texture	Fine loam	Clay loam to sandy clay loam
Slope	0 to 15 percent	0 to 15 percent
Shrink-swell potential	Low-moderate	Low-moderate
Permeability	Moderate; well-drained	Moderate; well-drained

Source: HRI 1988.

3.3 HYDROLOGY

3.3.1 Groundwater

3.3.1.1 Regional

Regional aquifers in northwestern New Mexico are grouped into multiple aquifer systems based on hydrologic relationships. At Church Rock, only the Dakota Sandstone and Morrison Formation present hydrologic concerns. At Crownpoint, additional shallower aquifers are found in the Mesaverde Group. The Dakota Sandstone is mostly unused as a water supply in McKinley County because of its generally poorer water quality.

The Westwater Canyon provides two valuable resources: uranium ore and high-quality groundwater. The Westwater Canyon is a classic example of an artesian aquifer. It is recharged from surface water infiltrating the rock in and around the Zuni and Defiance uplifts and moves in a down-dip direction toward the deeper parts of the San Juan basin (Kelly 1977). The topographically higher recharge areas create a hydraulic head, causing groundwater to rise in wells in the basin, some of which flow at the surface.

3.3.1.2 Crownpoint

With the exception of HRI-owned wells, there are no wells within the Crownpoint site boundary. Operating private wells in the area are widely dispersed. The nearest operating private well is located just outside the southwest boundary of the western half of the site. This is a private well drilled into the Gallup Sandstone of the Mesaverde Group. The next nearest operating private well is more than 0.5 mile distant from the site boundary. The nearest public water supply wells are located in the Town of Crownpoint, with wells located within 0.4 km (0.25 mile) of both the eastern and western site boundaries.

The Town of Crownpoint derives its water supply from six wells completed in the Westwater Canyon sandstone of the Morrison Formation. The water supply network is owned and operated by the BIA and the Navajo Tribal Utility Authority (NTUA). Five of the wells (BIA-5, BIA-3, BIA-6, NTUA-1, and NTUA-2) are found near the HRI's Crownpoint site, as shown in Figure 3-9. Each water-supply well has up to 150 m (500 ft) of screened interval within the Westwater Canyon Member (Table 3-11), thus exposing a relatively thick zone of saturated rock. Three of the Town of Crownpoint's water wells (BIA-5, BIA-3, and BIA-6) are completed in the Dakota Sandstone as well as the Westwater Canyon Member. In addition, well BIA-5 is also completed into the Cow Springs aquifer. HRI monitored water levels and pumping rates in these wells over several months (HRI 1992a) and found that each well is used sporadically and provides flow rates of 190 to 450 lpm (50 to 120 gpm).

The Town of Crownpoint water supply fits the definition of a "public water system" and the West Water Canyon Member and the Dakota Sandstone fit the definition of "Underground Sources of Drinking Water" in EPA's National Primary Drinking Water Regulations. A public water system is a system for provision to the public of piped water for human consumption, if such has at least fifteen service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year (40 CFR 141.2). Drinking-water storage is provided both below and above ground with a total capacity of 2.5 million liters (675,000 gallons). The BIA well capacities total 196,820 l/day (52,000 gpd) and NTUA well capacities total 870,187 l/d (229,904 gpd) (NRC 1994; Dalton 1995). Census figures indicate that the population of Crownpoint was 2108 persons occupying 673 total housing units in 1990 (NRC 1994). The Crownpoint water system also supplies water to the Crownpoint Boarding School, which has 568 students, and the Crownpoint Elementary and High schools, which have 646 and 638 students, respectively (NRC 1994). Water is also supplied to the Crownpoint Indian Hospital, with 56 beds and a hospital staff of 74, and the Community Health Service, which has a staff of 30 (NRC 1994).

Groundwater from the West Water Member near the Town of Crownpoint has a total dissolved concentration that ranges from 281 ppm to 3180 ppm and averages 773 ppm (HRI 1992b). Groundwater as measured in Dakota Sandstone well CP10 has a total dissolved concentration that averages 683 ppm (HRI 1992b). Even though the town's water supply wells are completed in sands that contain uranium deposits, radionuclide concentrations in the Crownpoint public water supply are low; uranium values range from 4.7 to 7.4 pCi/l, radium-226 from 0.18 to 0.29 pCi/l, and thorium-226 from 0.4 to 2.2 pCi/l (HRI 1995b). Water from the Town of Crownpoint water supply wells is of better quality than State of New Mexico drinking water quality standards.

An underground source of drinking water is an aquifer or its portion which: (1) supplies any public water system; or (2) contains a sufficient quantity of groundwater to supply a public water system; and (a) currently supplies drinking water for human consumption; (b) contains fewer than 10,000 mg/l total dissolved solids; and (c) is not an exempted aquifer (40 CFR 144.3). Water near the Town of Crownpoint in the West Water Canyon Member and the Dakota sandstone currently meets all of these criteria.

The first aquifer beneath the mine zone aquifer (Westwater Canyon) is the Cow Springs aquifer. Little information is available on this aquifer. The limited water quality data available are incomplete, but suggest that the Cow Springs aquifer contains good quality water (HRI 1996c). Reported transmissivity values are low, in the 35 m^2/d (374 gpd/ft) range, for most of the San Juan Basin (HRI 1996c). Head data indicate that the Cow Springs aquifer has higher hydraulic heads than the Morrison, which implies upward vertical flow in the Cow Springs aquifer. Well BIA-5 is completed into the Dakota Sandstone aquifer, the

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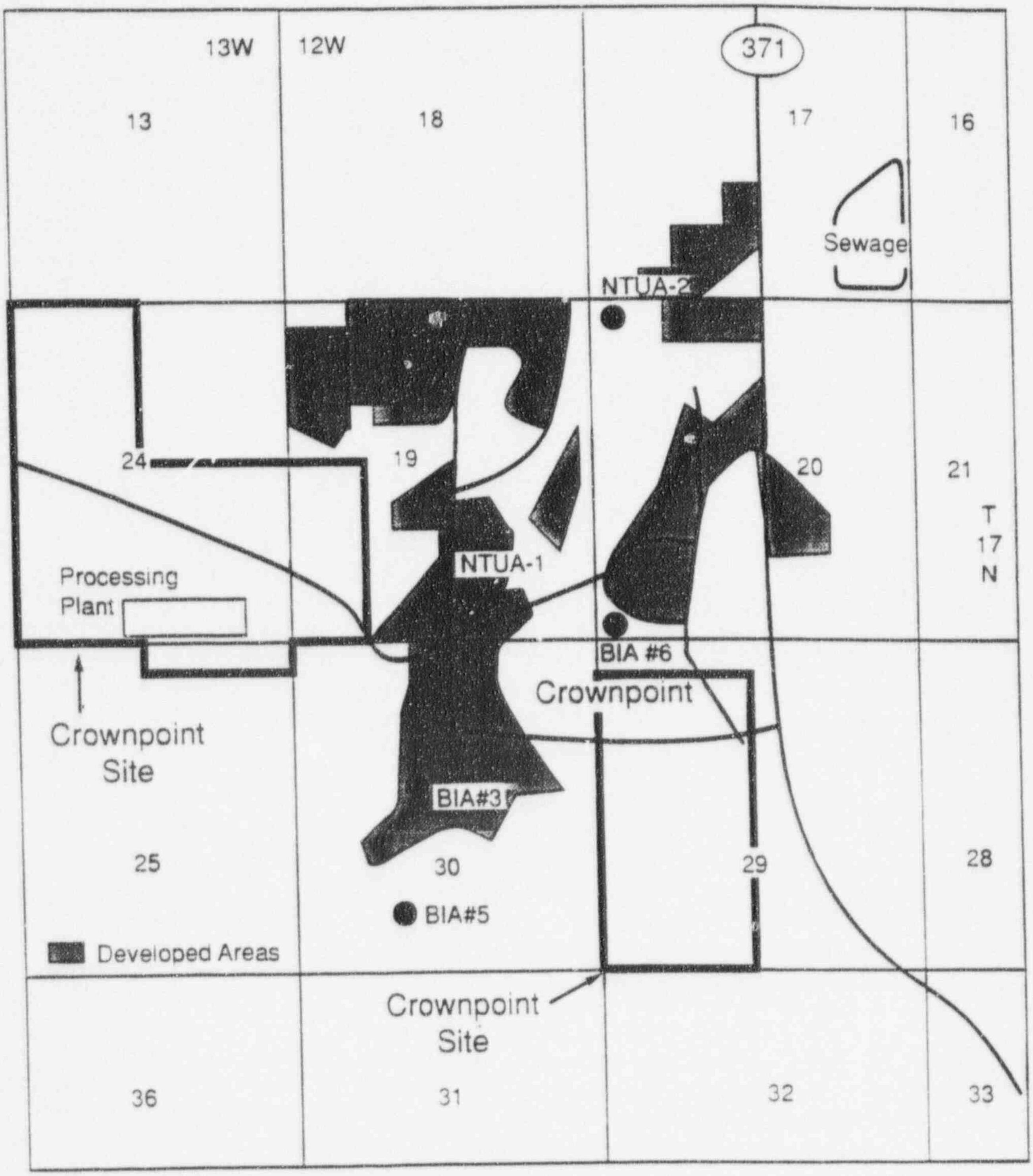

Figure 3-9. Municipal water-supply wells completed in the Westwater Canyon Sandstone in the Crownpoint area.

Table 3-11. Municipal water-supply wells in the Crownpoint area

Name	Total depth (meters)	Producing interval (meters)
NTUA-1	715	590–695
BIA-3	761	463–725
BIA-5	775	488–775
BIA-6	762	562–720
NTUA-2	725	654–715

Source: HRI 1992a.

Westwater Canyon aquifer, and the Cow Springs aquifer (HRI 1992b). In addition, a local well (Mobil Monument Windmill) located 0.5 mile east of the Crownpoint site in Section 28 appears to be completed into the Cow Springs aquifer as well as the Westwater Canyon and deeper units (HRI 1992b).

The Recapture Shale, which lies on top of the Cow Springs formation and is considered to be an aquitard, is about 79 m (260 ft) thick at the Crownpoint site. A large number of drill holes have been drilled into the Recapture Shale at each of the three project sites; however, most of these holes only penetrated the upper 1.5 m to 12.2 m (5 to 40 ft). None of the holes penetrated the entire thickness of the Recapture Shale (HRI 1993a). From an inspection of the materials submitted by HRI, NRC staff have not found any instances where the Recapture Shale is absent beneath the Crownpoint or Unit 1 sites.

Above the Recapture Shale is the Westwater Canyon Aquifer, which is an artesian aquifer. Water quality in the Westwater Canyon is good and usually meets New Mexico drinking water quality standards (Tables 3-12 and 3-13). The five town water wells and the windmill located in Section 28 are completed in the Westwater Canyon aquifer). In the Crownpoint area, the top of the Westwater Canyon is found at an elevation of approximately 1525 m (5000 ft), but water levels rise naturally in wells approximately 445 m (1460 ft) from the top of the Westwater aquifer to 75 m (240 ft) below the surface (HRI 1992a). The natural potentiometric surface slopes north-northeastward, but has been altered by pumping from drinking water supply wells in Crownpoint.

A potentiometric surface map of the Westwater aquifer for the Unit 1 and Crownpoint sites was prepared using a calibrated flow model to match monitor well level data collected in the summer of 1992 (Figure 3-10) (HRI 1996a). Summer water-level gradients were modeled because they tend to be steeper than winter gradients due to increased pumping from the Town of Crownpoint water wells. This model was then used to calculate groundwater gradients for those areas in and around the Town of Crownpoint that do not have monitor wells. The potentiometric map shows that in all directions, local groundwater flow is toward the Town of Crownpoint water wells. Calculated groundwater flow velocities based on the piezometric surface map for the Crownpoint site ranged from 3.9 m/yr (12.9 ft/yr) in the east to 2.4 m/yr (8 ft/yr) at the west side of the site (HRI 1996a).

Table 3-12. Town of Crownpoint water quality data[a]

Parameter	Well NTUA-1 (mg/l)	Well NTUA-2 (mg/l)	Wells BIA-5&6 (mg/l)	Well BIA-6 (mg/L)	EPA drinking water standards (mg/l)
Calcium	5.0	1.3	9.2	1.8	
Magnesium	2.0	0.08	4.5	0.14	
Sodium	131.0	121.0	119.0	111.0	
Potassium	4.9	1.2	2.3	1.7	
Carbonate	17.0	20.0	1.0	8.0	
Bicarbonate	234.0	221.0	249.0	223.0	
Sulfate	82.0	52.0	98.0	49.0	250.0
Chloride	7.7	3.2	3.2	2.0	250.0
Nitrate	0.01	0.02	0.02	0.01	10.0
Fluoride	1.1	0.32	0.34	0.27	4.0 or 2.0
Silica	10.0	18.0	20.0	18.0	
TDS	402.0	351.0	406.0	325.0	500.0
Conductivity[b]	625.0	529.0	603.0	484.0	
Alkalinity	220.0	215.0	206.0	197.0	
pH[c]	8.79	8.91	8.33	8.7	6.5–8.5
Arsenic	<0.001	<0.001	<0.001	<0.001	0.05
Barium	0.02	0.05	0.05	0.06	2.0
Cadmium	0.0002	<0.0001	<0.0001	<0.001	0.01
Chromium	<0.01	<0.01	<0.01	<0.01	0.05
Copper	<0.01	<0.01	<0.01	<0.01	1.0
Iron	0.02	<0.01	0.01	<0.01	0.3
Lead	<0.001	0.002	<0.001	<0.001	0.05
Manganese	0.01	0.01	<0.1	<0.01	0.05
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	0.002
Molybdenum	<0.01	<0.01	<0.01	<0.01	
Nickel	<0.01	<0.01	<0.01	<0.01	0.1
Selenium	<0.001	<0.001	<0.001	<0.001	0.05
Silver	<0.01	<0.01	<0.01	<0.01	0.1
Uranium	<0.001	<0.001	0.007	<0.001	
Vanadium	<0.01	<0.01	<0.01	<0.01	
Zinc	0.01	0.01	<0.01	<0.01	5.0
Boron	0.05	0.06	0.07	0.05	
Ammonia	<0.01	<0.01	<0.01	<0.01	
Radium-226[d]	0.6	0.3	0.6	0.3	5.0

[a]Data collected September 1990 (HRI 1996i).
[b]µmhos/cm.
[c]Unitless.
[d]pCi/L

Table 3-13. Crownpoint site water quality data,[a] Westwater Canyon Aquifer

Parameter	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	New Mexico drinking water standard
Calcium	2.68	7.8	0.07	
Magnesium	0.44	2.5	0.0	
Sodium	120.3	184.0	97.0	
Potassium	10.58	56.0	1.5	
Carbonate	26.42	127.0	0.0	
Bicarbonate	201.22	260.0	54.0	
Sulfate	54.9	177.0	19.0	600.0
Chloride	10.9	54.0	1.8	250.0
Nitrate	0.05	0.26	0.0	10.0
Fluoride	0.35	0.5	0.23	1.6
Silica	16.2	20.0	1.0	
TDS	367.8	666.0	318.0	1000.0
Conductivity[b]	700.5	1040.0	463.0	
Alkalinity	209.3	256.0	193.0	
pH[c]	9.0	10.4	8.26	6–9
Arsenic	0.0	0.001	0.0	0.1
Barium	0.05	1.0	0.0	1.0
Cadmium	0.0	0.0008	0.0	0.01
Chromium	0.0	0.0	0.0	0.05
Copper	0.0	0.92	0.0	1.0
Iron	0.03	0.1	0.0	1.0
Lead	0.0	0.013	0.0	0.05
Manganese	0.0	0.029	0.0	0.2
Mercury	0.0	0.0	0.0	0.002
Molybdenum	0.0	0.02	0.0	
Nickel	0.0	0.0	0.0	
Selenium	0.0	0.0	0.0	0.05
Silver	0.0	0.0	0.0	0.05
Uranium[d]	0.001	0.021	0.0	5.0
Vanadium	0.0	0.0	0.0	
Zinc	0.0	0.03	0.0	10.0
Boron	0.06	0.11	0.0	
Ammonia	0.03	0.31		
Radium-226[d]	65.85	806.0	0.1	30.0

[a]Values obtained from Wells CP-3, CP-5, CP-6, CP-7, CP-9, and well CP-2 (for parameters from arsenic to radium-226 (Source: HRI 1992b).

[b]μmhos/cm.

[c]Unitless.

[d]pCi/L

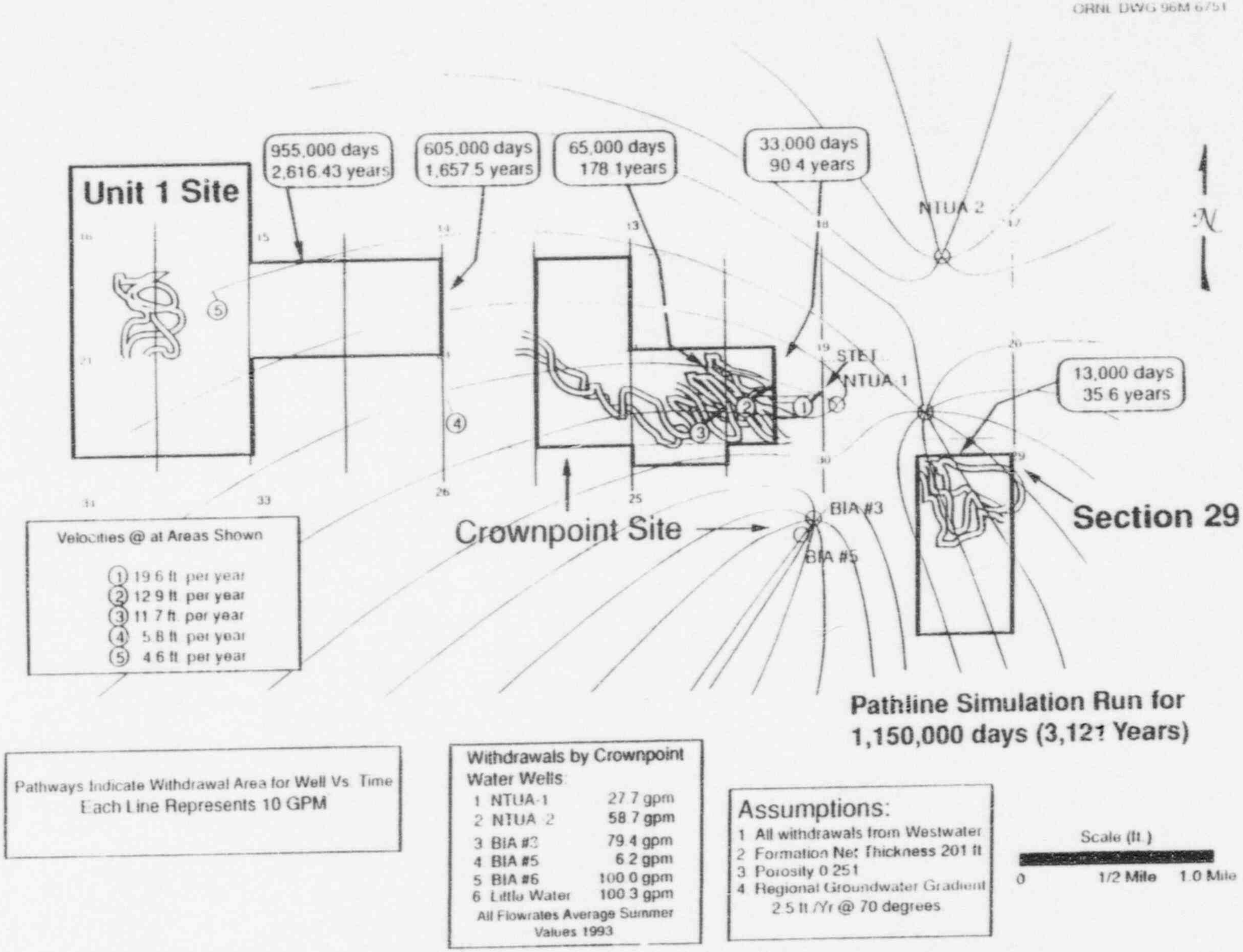

Figure 3-10. Modeled groundwater flow pathways for the Unit 1 and Crownpoint sites.

The Brushy Basin shale overlies the mineralized zone and is considered an aquitard in the area (HRI 1992b). At the Crownpoint site, the Brushy Basin member does not contain any aquifers and consists entirely of shale (HRI 1992b). From an inspection of the materials submitted by HRI, staff have not found any instances where the Brushy Basin shale is absent beneath the Crownpoint or Unit 1 sites.

The Dakota sandstone is an artesian aquifer that overlies the Brushy Basin shale. Water quality in the Dakota Sandstone aquifer is good and meets New Mexico drinking water quality standards (Table 3-14). Three of the town water supply wells are completed into the Dakota Sandstone. Comparisons of water-level data between the Dakota Sandstone aquifer and the Westwater Canyon aquifer indicate that the vertical flow in the Dakota Sandstone is downward (HRI 1992b). Lateral groundwater flow in the Dakota Sandstone at the Crownpoint site has not been accurately determined because of insufficient numbers of monitoring wells (HRI 1996a). Natural groundwater flow in the Dakota prior to Crownpoint water well pumping is projected to be toward the north. The hydraulic gradient in the Dakota Sandstone aquifer, in the Crownpoint area, is believed to be similar to the Westwater due to groundwater pumping by the Town of Crownpoint. Given the lack of data on lateral flow in the Dakota sandstone, NRC staff have assumed that groundwater in the Dakota Sandstone beneath the Crownpoint property flows towards the Town of Crownpoint wells.

Between 183 m and 213 m (600–700 ft) of Mancos Shale lie above the Dakota Sandstone. The Mesaverde Group lies on top the Mancos Shale. The Mesaverde Group contains a number of sands, the lowermost being the Gallup Sandstone. There are no other geologic units above the Mesaverde, since it forms the surficial unit at the sites. One well is drilled in the Gallup Sandstone in the Mesaverde Group at the southwest corner of the Crownpoint site boundary in Section 25.

HRI has monitored water levels and conducted pump tests at the Crownpoint site. Pump tests were conducted in the Westwater Canyon aquifer to determine the hydraulic properties of the ore-bearing sandstone, and to determine the degree of vertical hydraulic confinement between the Dakota Sandstone and the Westwater Canyon aquifer. The test was performed for 72 hours from April 17 through April 20, 1992, pumping from a Westwater Canyon well located near the Crownpoint site surface facilities. One monitor well was completed in the Dakota Sandstone and five monitor wells were completed in the Westwater Canyon. Analysis of the pump test data was complicated by the pumping influence from the Town of Crownpoint water supply wells, which occurred during the test. The results indicated that transmissivities range from 237 m^2/d to 251 m^2/d (2,556 gpd/ft to 2,698 gpd/ft) (Table 3-15). No aquifer interconnection was detected by the test (i.e., no draw down was detected by the Dakota Sandstone monitor wells).

3.3.1.3 Unit 1

No wells are located within the Unit 1 site boundary. Operating private wells in the area are widely dispersed. The nearest operating private well is located 0.4 km (0.25 mile) west of the site boundary. This is a private well drilled into the aquifers in the Mesaverde Group. The next nearest operating private well is more than 0.8 km (0.5 mile) southeast of the site boundary and is completed in Gallup Sandstone of the Mesaverde Group. No other private wells occur within 3.2 km (2 miles) of the Unit 1 site boundary. The nearest public water supply wells are located 3.2 km (2 miles) away in the Town of Crownpoint.

The aquifer formations located beneath the Unit 1 site are the same as those beneath the Crownpoint site. As discussed in Section 3.3.1.2, water quality in the Westwater Canyon beneath the Crownpoint and Unit 1

Table 3-14. Crownpoint site water quality data,[a] Dakota Sandstone Aquifer

Parameter	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	New Mexico drinking water standard
Calcium	2.0	2.2	1.9	
Magnesium	0.1	0.17	0.11	
Sodium	225.3	231.0	217.0	
Potassium	2.5	3.8	1.5	
Carbonate	38.5	58.0	16.0	
Bicarbonate	207.0	243.0	161.0	
Sulfate	244.8	251.0	227.0	600.0
Chloride	6.0	9.6	3.9	250.0
Nitrate	0.1	0.24	0.0	10.0
Fluoride	0.6	0.72	0.55	1.6
Silica	13.0	18.0	3.0	
TDS	682.8	693.0	671.0	1000.0
Conductivity[b]	991.3	1000.0	981.0	
Alkalinity	233.0	251.0	225.0	
pH[c]	9.0	9.31	8.81	6–9
Arsenic	0.0	0.0	0.0	0.1
Barium	0.05	0.05	0.01	1.0
Cadmium	0.0	0.0	0.0	0.01
Chromium	0.0	0.0	0.0	0.05
Copper	0.0	0.0	0.0	1.0
Iron	0.1	0.13	0.0	1.0
Lead	0.0	0.004	0.0	0.05
Manganese	0.01	0.01	0.01	0.2
Mercury	0.0	0.0	0.0	0.002
Molybdenum	0.0	0.01	0.0	
Nickel	0.0	0.0	0.0	
Selenium	0.0	0.0	0.0	0.05
Silver	0.0	0.0	0.0	0.05
Uranium[d]	0.0	0.0	0.0	5.0
Vanadium	0.0	0.0	0.0	
Zinc	0.0	0.0	0.0	10.0
Boron	0.2	0.2	0.14	
Ammonia	0.05	0.08	0.03	
Radium-226[d]	0.6	0.9	0.4	30.0

[a]Source: HRI 1992b.
[b]μmhos/cm.
[c]Unitless.
[d]pCi/l.

Table 3-15. Crownpoint site hydrologic parameters

Geologic unit	Transmissivity: Well	Transmissivity: m^2/d (gpd/ft)	Storage coefficient (dimensionless)
Westwater Canyon	CP-2	245 m^2/d (2,641)	9.00E-5
Westwater Canyon	CP-3	237 m^2/d (2,556)	7.80E-5
Westwater Canyon	CP-6	274 m^2/d (2,953)	1.13E-4
Westwater Canyon	CP-7	237 m^2/d (2,556)	1.39E-4
Westwater Canyon	CP-8	251 m^2/d (2,698)	4.50E-5

Source: HRI 1992b.

sites is good and usually meets New Mexico drinking water quality standards (Table 3-16). Similarly, water quality in the Dakota Sandstone aquifer is good and meets New Mexico drinking water quality standards (Table 3-17).

A potentiometric surface map of the Westwater aquifer for the Unit 1 and Crownpoint sites was prepared using a calibrated flow model to match monitor well level data collected in the summer of 1992 (Figure 3-10). For the Unit 1 site, calculated groundwater flow velocities based on the piezometric surface map averaged 1.5 m/yr (5 ft/yr) in the Westwater aquifer (HRI 1996a).

HRI's application provides water quality, water level, and pump test data collected by Mobil Oil Company at the Unit 1 site. Pump tests were conducted by Mobil in the Westwater Canyon aquifer to determine the hydraulic properties of the ore-bearing sandstone and to determine the degree of vertical hydraulic confinement between the Dakota Sandstone and the Westwater Canyon aquifer (HRI 1993; HRI 1995a; HRI 1995b). The test was performed from August 16 through 18, 1982, with two wells completed in the Dakota Sandstone and 27 wells completed in the Westwater Canyon Member. The results indicated that transmissivities ranged from 84 m^2/d to 133 m^2/d (905 gpd/ft to 1,432 gpd/ft) (Table 3-18). No aquifer interconnection was detected by the test (i.e., no draw down was detected by the Dakota Sandstone monitor wells).

3.3.1.4 Church Rock

With the exception of HRI-owned wells, there are no wells within the Church Rock site boundary. This site is far away from any towns and any operating private wells in the area are widely dispersed. The nearest operating private well is located just outside the southern boundary of the site and is completed in the Dakota Sandstone. There are no other wells within one mile of the site.

The aquifer formations located beneath the Church Rock site are similar to those beneath the Crownpoint and Unit 1 sites. The Recapture Shale at the Church Rock site is about 55 m (180 ft) thick. Water quality in the Westwater Canyon beneath the Church Rock site is good and usually meets New Mexico drinking water quality standards (Table 3-19).

Table 3-16. Unit 1 site water quality data,[a] Westwater Canyon Aquifer

Parameter	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	New Mexico drinking water standard
Calcium	3.75	18.0	1.1	
Magnesium	0.145	9.2	0.0	
Sodium	113.0	1100.0	82.0	
Potassium	1.95	12.0	0.7	
Carbonate	12.0	120.0	0.0	
Bicarbonate	206.0	270.0	89.0	
Sulfate	35.5	220.0	20.0	600.0
Chloride	5.5	41.0	<3.0	250.0
Nitrate	0.03	1.8	<0.05	10.0
Fluoride	0.1	0.4	<0.5	1.6
Silica	18.5	23.0	11.0	
TDS	285.0	590.0	0.0	1000.0
Conductivity[b]	402.5	820.0	0.0	
pH[c]	8.75	9.1	7.5	6.0–9.0
Arsenic	<0.005	<0.005	<0.005	0.1
Barium	<0.2	0.4	<0.2	1.0
Cadmium	<0.005	<0.005	<0.005	0.01
Chromium	0.003	0.008	<0.005	0.05
Copper	0.0405	0.980	<0.005	1.0
Iron	0.04	1.0	<0.01	1.0
Lead	0.0095	0.170	<0.005	0.05
Manganese	0.0035	0.034	<0.005	0.2
Mercury	<0.0001	<0.0001	<0.0001	0.002
Molybdenum	0.0035	0.016	<0.005	
Nickel	<0.02	0.02	<0.02	
Selenium	<0.005	<0.006	<0.005	0.05
Silver	<0.005	<0.005	<0.005	0.05
Uranium[d]	2.0	2.7	0.68	5.0
Zinc	0.023	0.800	<0.005	10.0
Boron	0.01	0.5	<0.1	
Radium-226[d]	10.3	200.0	0.0	30.0
Gross alpha[d]	42.0	610.0	0.0	
Gross beta[d]	43.0	510.0	0.0	
Radon[d]	81699.0	1100000.0	22.0	

[a]*Source*: HRI 1992b.
[b]µmhos/cm.
[c]Unitless.
[d]pCi/l.

Table 3-17. Unit 1 site water quality data,[a] Dakota Sandstone Aquifer

Parameter	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	New Mexico drinking water standard
Calcium	17.0	18.0	16.0	
Magnesium	8.53	9.2	7.5	
Sodium	163.0	170.0	150.0	
Potassium	3.3	3.6	2.9	
Carbonate	0.0	0.0	0.0	
Bicarbonate	263,0	270.0	250.0	
Sulfate	209.0	220.0	187.0	600.0
Chloride	4.0	6.0	<3.0	250.0
Nitrate	0.02	0.07	<0.05	10.0
Fluoride	0.1	0.5	<0.2	1.6
Silica	18.0	21.0	15.0	
TDS	554.0	590.0	536.0	1000.0
Conductivity[b]	786.0	820.0	740.0	
pH[c]	7.6	7.7	7.5	6.0–9.0
Arsenic	<0.005	<0.005	<0.005	0.1
Barium	0.1	0.4	<0.2	1.0
Cadmium	<0.005	<0.005	<0.005	0.01
Copper	0.001	0.005	<0.005	1.0
Iron	0.01	0.02	<0.01	1.0
Lead	<0.005	<0.005	<0.005	0.05
Manganese	0.032	0.034	0.030	0.2
Mercury	<0.0001	<0.0001	<0.0001	0.002
Molybdenum	0.002	0.008	<0.005	
Nickel	<0.02	<0.02	<0.02	
Selenium	<0.005	<0.005	<0.005	0.05
Silver	<0.005	<0.005	<0.005	0.05
Uranium[d]	0.68	2.0	0.68	5.0
Zinc	0.004	0.01	<0.005	10.0
Boron	<0.1	0.2	<0.1	
Radium-226[d]	1.3	2.0	0.0	30.0
Gross alpha[d]	2.0	5.0	0.0	
Gross beta[d]	6.0	10.0	3.0	
Radon[d]	1175.0	4400.0	22.0	

[a] *Source*: HRI 1996b.

[b] μmhos/cm.

[c] Unitless.

[d] pCi/l.

Table 3-18. Unit 1 site hydrologic parameters

Geologic unit	Transmissivity		Storage coefficient (dimensionless)
	Well	m^2/d (gpd/ft)	
Westwater Canyon	15L5	102 m^2/d (1,102)	8.9E-5
Westwater Canyon	15L7	114 m^2/d (1,228)	7.0E-5
Westwater Canyon	15L17	84 m^2/d (905)	1.6E-4
Westwater Canyon	15L17a	133 m^2/d (1,432)	5.4E-5
Westwater Canyon	15L36	84 m^2/d (914)	4.6E-5
Westwater Canyon	15L45	109 m^2/d (1,177)	9.4E-5
Westwater Canyon	15L64	114 m^2/d (1,228)	4.6E-5
Westwater Canyon	15L73	110 m^2/d (1,194)	9.1E-5
Westwater Canyon	15M12	133 m^2/d (1,432)	8.5E-5
Westwater Canyon	15M35	99 m^2/d (1,062)	6.9E-5
Westwater Canyon	15M39	100 m^2/d (1,074)	1.1E-4
Westwater Canyon	15M63	109 m^2/d (1,177)	6.0E-4
Westwater Canyon	15M67	114 m^2/d (1,228)	2.8E-4
Westwater Canyon	15M92	133 m^2/d (1,432)	6.7E-5
Westwater Canyon	15M94	131 m^2/d (1,409)	7.9E-5
Westwater Canyon	16I11	114 m^2/d (1,228)	6.6E-5
Westwater Canyon	16I23	119 m^2/d (1,283)	5.0E-5
Westwater Canyon	16I51	119 m^2/d (1,283)	4.9E-5
Westwater Canyon	16I81	114 m^2/d (1,228)	3.7E-5
Westwater Canyon	16I85	107 m^2/d (1,162)	1.1E-4
Westwater Canyon	16P11	113 m^2/d (1,211)	6.4E-5
Westwater Canyon	16P37	106 m^2/d (1,146)	5.4E-5
Westwater Canyon	16P65	117 m^2/d (1,264)	5.5E-5
Westwater Canyon	16P80	117 m^2/d (1,264)	—
Westwater Canyon	16P94	123 m^2/d (1,322)	5.9E-5
Westwater Canyon	16P96	131 m^2/d (1,409)	6.5E-5
Westwater Canyon	16P102	131 m^2/d (1,409)	7.2E-5

Source: HRI 1996a.

Table 3-19. Church Rock site water quality data,[a] Westwater Canyon Aquifer

Parameter	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	New Mexico drinking water standard
Calcium	2.775	5.8	1.5	
Magnesium	0.235	0.81	0.07	
Sodium	129.75	148.0	114.0	
Potassium	2.46	6.6	0.85	
Carbonate	28.75	80.0	0.0	
Bicarbonate	246.25	331.0	185.0	
Sulfate	37.0	46.0	32.0	600.0
Chloride	6.15	12.0	2.8	250.0
Nitrate	0.02	0.16	0.01	10.0
Fluoride	1.628	22.0	0.21	1.6
Silica	16.5	68.0	11.0	
TDS	369.75	435.0	322.0	1000.0
Conductivity[b]	556.25	651.0	485.0	
Alkalinity	256.0	491.0	218.0	
pH[c]	8.923	9.67	8.15	6.0–9.0
Arsenic	0.0025	0.012	0.001	0.1
Barium	0.0675	0.12	0.02	1.0
Cadmium	0.00028	0.005	0.0001	0.01
Chromium	0.0125	0.07	0.01	0.05
Copper	0.0125	0.08	0.01	1.0
Iron	0.0375	0.29	0.01	1.0
Lead	0.001	0.003	0.001	0.05
Manganese	0.01	0.01	0.01	0.2
Mercury	0.0001	0.0001	0.0001	0.002
Molybdenum	0.01	0.04	0.01	
Nickel	0.01	0.01	0.01	
Selenium	0.00125	0.01	0.001	0.05
Silver	0.01	0.01	0.01	0.05
Uranium[d]	1223.0	7083.0	1.362	5.0
Zinc	0.01	0.03	0.01	10.0
Boron	0.1	0.65	0.04	
Ammonia	0.0775	0.16	0.01	
Radium-226[d]	10.225	26.0	1.1	30.0

[a]*Source*: HRI 1996b.

[b]µmhos/cm.

[c]Unitless.

[d]pCi/l.

A piezometric surface map of the Church Rock property was prepared by mapping water level data collected in March 1993. The potentiometric surface slopes north-northeastward and is roughly parallel to the structural dip of the sedimentary rocks in the region. The potentiometric surface slopes approximately 0.41 degrees from 2012 to 1995 m msl (6600 to 6550 ft msl) in elevation (Figure 3-11). The calculated groundwater flow velocity is 2.7 m/yr (8.7 ft/yr) (Reed 1993).

At the Church Rock site, the top of the Brushy Basin shale contains the "B" sand. The "B" sand is an artesian aquifer that is 4 to 9 m (13 to 28 ft) thick, with 5 to 10 m (16 to 32 ft) of mudstone between it and the top of the Westwater Canyon aquifer and 5 to 10 m (16 to 33 ft) of mudstone between it and the bottom of the Dakota Sandstone aquifer. Water quality in the Brushy Basin "B" sand is good (Table 3-20).

Similarly, water quality in the Dakota Sandstone aquifer at the Church Rock site is good and meets New Mexico drinking water quality standards (Table 3-21). HRI believes that the lateral direction of groundwater flow in the Dakota Sandstone at the Church Rock site is northerly (HRI 1996a). However, lateral groundwater flow has not been determined accurately at this time due to the lack of sufficient monitoring wells (HRI 1996a).

HRI has monitored water levels and conducted pump tests at the Church Rock site. In September and October 1988, pump tests were conducted in the Westwater Canyon aquifer to determine the hydraulic properties of ore-bearing sandstone and to determine the degree of vertical hydraulic confinement between the Dakota Sandstone aquifer, the Brushy Basin "B" Sand aquifer, and the Westwater Canyon aquifer. Additional data from monitor wells were used to determine the degree of hydraulic communication that exists between the mineralized zone and perimeter monitoring points. Four wells were completed in the Westwater Canyon aquifer, one was completed in the Brushy Basin "B" Sand aquifer, and one was completed in the Dakota Sandstone aquifer. The results indicated that transmissivities ranged from 86 m^2/d to 123 m^2/d (926 gpd/ft to 1,326 gpd/ft) (Table 3-22). No aquifer interconnection was detected by the test (i.e., no draw down was detected by the Dakota Sandstone or Brushy Basin "B" Sand monitor wells). To further verify the properties of the aquitards, HRI undertook a laboratory study. Through this study, HRI tested core samples of the aquitard materials and found that they have sufficiently less vertical permeability than the Westwater Canyon aquifer.

The Church Rock site also contains another pre-existing hydrologic feature. In Section 24 at the southern end of the site, large vertical mine shafts are connected to tunnels constructed in the Westwater Canyon aquifer and the "B" Sand aquifer. HRI believes that most of the tunnels are intact and have not collapsed (HRI 1993a). A review by HRI of the mine workings maps indicates no tunnels extend beyond the boundaries of the proposed solution mining areas (HRI 1993a).

3.3.2 Surface Water

3.3.2.1 Regional

Western New Mexico's semi-arid climate gives the project area characteristically high surface evaporation rates. Significant runoff is rarely observed in the project sites because most of the run[illegible] infiltrates the ground, or evaporates locally. The average annual pan evaporation rate for Gall[illegible] (75 in) (HRI 1988). Information on pond evaporation rates varies, but the average is approxim[illegible] cm (86 in) per year.

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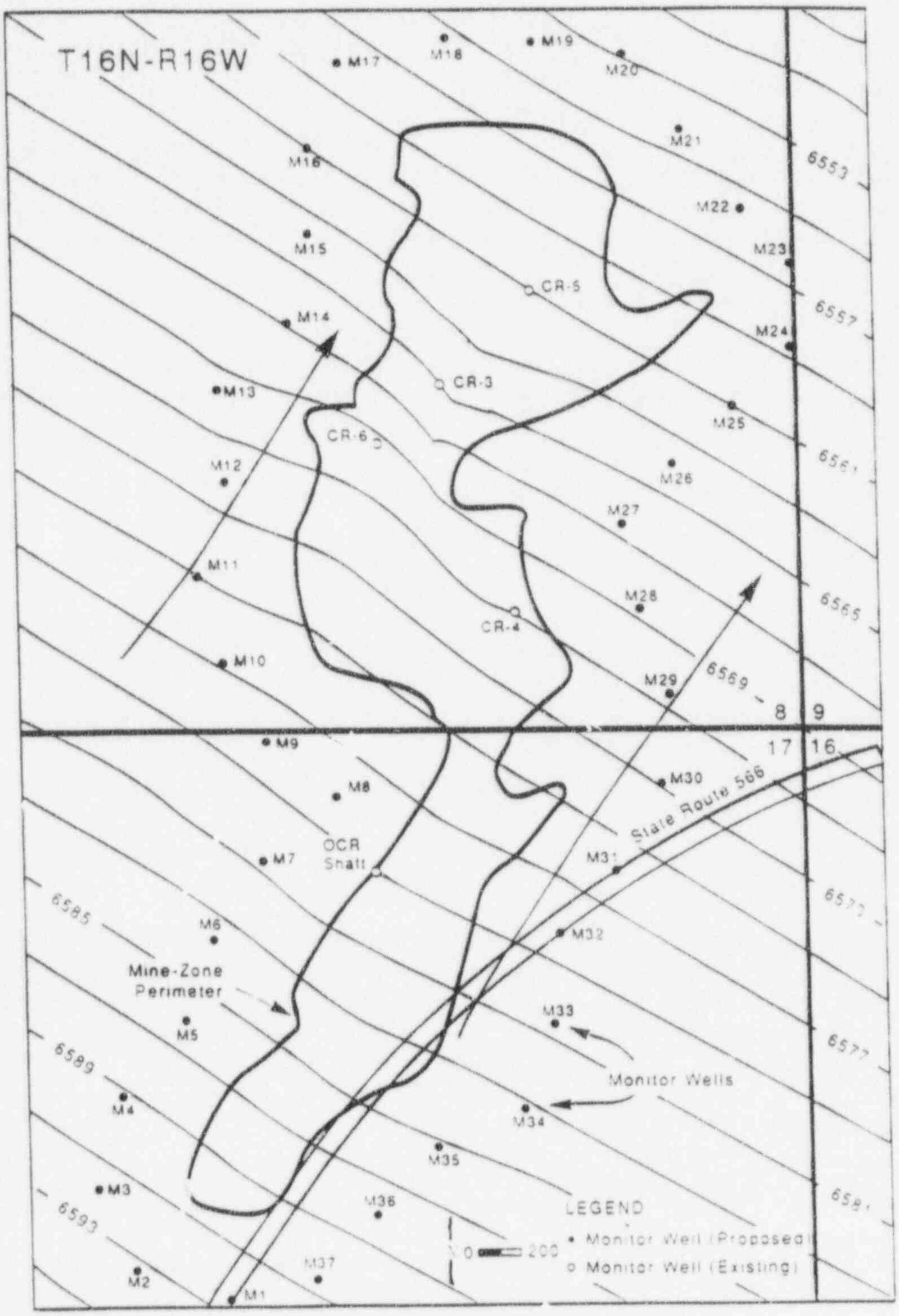

Figure 3-11. Potentiometric surface of the Westwater Canyon Sandstone at the Church Rock site.

Table 3-20. Church Rock site water quality data,[a] Brushy Basin "B" Sandstone Aquifer

Parameter	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	New Mexico drinking water standard
Calcium	7.5	32.0	1.9	
Magnesium	0.03	0.05	0.01	
Sodium	166.0	248.0	141.0	
Potassium	10.8	31.0	3.9	
Carbonate	92.0	146.0	27.0	
Bicarbonate	66.0	148.0	0.0	
Hydroxide	36.0	160.0	0.0	
Sulfate	77.0	96.0	71.0	600.0
Chloride	3.8	6.1	1.6	250.0
Nitrate	0.03	0.07	0.01	10.0
Fluoride	0.66	0.79	0.57	1.6
Silica	23.0	37.0	15.0	
TDS	480.0	658.0	415.0	1000.0
Conductivity[b]	1073.0	2520.0	391.0	
Alkalinity	319.0	560.0	249.0	
pH[c]	10.5	12.0	9.77	6.0–9.0
Arsenic	0.002	0.004	0.001	0.1
Barium	0.03	0.16	0.01	1.0
Cadmium	0.0002	0.001	0.0001	0.01
Chromium	0.01	0.01	0.01	0.05
Copper	0.03	0.14	0.01	1.0
Iron	0.04	0.08	0.02	1.0
Lead	0.019	0.121	0.001	0.05
Manganese	0.01	0.01	0.01	0.2
Mercury	0.0001	0.0001	0.0001	0.002
Molybdenum	0.01	0.03	0.01	
Nickel	0.01	0.02	0.01	
Selenium	0.002	0.009	0.001	0.05
Silver	0.01	0.01	0.01	0.05
Uranium[d]	3.4	8.9	0.68	5.0
Vanadium	0.01	0.02	0.01	
Zinc	0.01	0.03	0.01	10.0
Boron	0.21	0.72	0.1	
Ammonia	0.59	2.8	0.04	
Radium-226[d]	1.1	9.6	0.01	30.0

[a] *Source*: HRI 1996b.

[b] μmhos/cm.

[c] Unitless.

[d] pCi/l.

Table 3-21. Church Rock site water quality data,[a] Brushy Basin "B" Sandstone Aquifer

Parameter	Mean (mg/l)	Maximum (mg/l)	Minimum (mg/l)	New Mexico drinking water standard
Calcium	3.0	3.7	2.5	
Magnesium	0.43	0.66	0.29	
Sodium	300.0	317.0	285.0	
Potassium	2.1	4.4	1.3	
Carbonate	23.0	67.0	5.0	
Bicarbonate	550.0	600.0	441.0	
Sulfate	126.0	130.0	120.0	600.0
Chloride	35.0	43.0	31.0	250.0
Nitrate	0.04	0.14	0.01	10.0
Fluoride	4.7	5.1	4.3	1.6
Silica	14.0	19.0	11.0	
TDS	835.0	875.0	812.0	1000.0
Conductivity[b]	1287.0	1360.0	1230.0	
Alkalinity	491.0	514.0	474.0	
pH[c]	8.7	9.25	8.45	6.0–9.0
Arsenic	0.001	0.002	0.001	0.1
Barium	0.04	0.11	0.01	1.0
Cadmium	0.0003	0.0015	0.0001	0.01
Chromium	0.01	0.01	0.01	0.05
Copper	0.01	0.01	0.01	1.0
Iron	0.06	0.18	0.01	1.0
Lead	0.006	0.022	0.001	0.05
Manganese	0.01	0.02	0.01	0.2
Mercury	0.0002	0.001	0.0001	0.002
Molybdenum	0.01	0.03	0.01	
Nickel	0.01	0.01	0.01	
Selenium	0.001	0.003	0.001	0.05
Silver	0.01	0.01	0.01	0.05
Uranium[d]	24.0	233.0	0.68	5.0
Vanadium	0.01	0.01	0.01	
Zinc	0.02	0.04	0.01	10.0
Boron	0.87	1.2	0.76	
Ammonia	0.14	0.25	0.05	
Radium-226[d]	0.6	1.0	0.2	30.0

[a] *Source*: HRI 1996b.
[b] μmhos/cm.
[c] Unitless.
[d] pCi/l.

Table 3-22. Church Rock site hydrologic parameters

Geologic unit	Well	Transmissivity m^2/d (gpd/ft)	Storage coefficient (dimensionless)
Westwater Canyon	CR-5	86 m^2/d (926)	8.90E-5
Westwater Canyon	CR-6	112 m^2/d (1,208)	4.13E-4
Westwater Canyon	CR-8	123 $m^2/$ (1,326)	3.00E-4

Source: HRI 1993a.

3.3.2.2 Crownpoint

Runoff from the Crownpoint area results from rainfall and snow melt occurring on site and in the sandstone highlands to the south. The surficial drainage network is poorly developed in the area, and consists mainly of numerous unnamed subparallel ephemeral washes originating in the highland and crossing the area. All the washes coalesce to the north and ultimately drain to the Chaco River 48 km (30 mi) north of Crownpoint.

Runoff occurs in the area mainly during peak periods of precipitation, typically during the wettest time of year from July through October. Surface runoff is unlikely from October through June. Surficial deposits commonly intercept and absorb much of the precipitation and snow melt.

3.3.2.3 Unit 1

The Unit 1 site's general surface water characteristics are similar to those of the Crownpoint site. TVA (1979) analyzed several watersheds, including the Unit 1 area, and determined that calculated mean annual discharges from various drainage basins in the area would be 0.63 to 1.07 cm (0.25 to 0.42 in). Table 3-23 describes a watershed heading in the highlands and encompassing most of Unit 1.

3.3.2.4 Church Rock

The Church Rock site is located near Pipeline Canyon, a tributary to the North Fork of the Puerco River. All of the water courses within the North Fork drainage are ephemeral washes. The Church Rock site is crossed by a small unnamed arroyo draining a small watershed that heads in the sandstone highland to the north.

Downstream use of surface water is limited to occasional livestock watering. Shallow groundwater in the alluvium in the North Fork is tapped by several shallow wells. This water is derived from storm flows passing down the arroyos and is pumped for domestic and stock-watering use.

HRI has analyzed the Church Rock site's surface hydrology (HRI 1993d). The land surface in the Church Rock lease area exhibits gentle slopes between 1 and 3 degrees toward the arroyo that traverses southwesterly across the site. The unnamed arroyo is a tributary to the Puerco River, and is incised from

Table 3-23. Unit 1 site watershed characteristics

Drainage area	9.7 mi^2 25.12 km^2
Average slope	0.040 212 ft/mi 40.16 m/km
Mean annual discharge	0.28 cfs 7.93 l/s 202 acre-feet 0.249 hm^3
Runoff	0.39 inches 0.99 cm
50-year flood peak discharge	1390 cfs 39 cms

Cfs = cubic feet per second; l/s = liters per second; cms = cubic meters per second; hm^3 = hectare-meter

Source: TVA 1979.

1 m (3 ft) at the downstream location to 5 m (17 ft) in the northernmost portion of the site. The watershed drained by this arroyo is approximately 10 km^2 (3.9 mi^2).

Surface hydrology and erosion potential in the channels were analyzed using U.S. Army Corps of Engineers models HEC-1 and HEC-2. The arroyo's 100-year water level is found within the steep banks formed by the arroyo walls throughout most of the site. Therefore, flow concentrations in the site area during a 100-year runoff event would be confined to the arroyo channel, except at the southern end of the site where flood water would spread onto a floodplain. The remainder of the site would experience sheet runoff or insignificant flow concentrations. The predicted depth of channel scour during runoff events of this magnitude is approximately 30 cm (1 foot). The results of runoff modeling are summarized in Table 3-24.

3.4 TRANSPORTATION

This section provides a description of the existing road network in the region surrounding the project sites. The road network would be used for: (1) shipments of yellowcake slurry or resin from the satellite processing facilities to the main processing facility; (2) shipments of refined yellowcake from the main processing facility to a uranium conversion facility in Illinois; and (3) shipments of process chemicals from suppliers to the processing facilities. Only road transportation is proposed for this project. Truck accident rates for roads in the region are specified based on 1990–1994 State of New Mexico and/or Navajo Nation data.

Table 3-24. Calculated peak runoff flow rates from the 25- and 100-year frequency storm events at Church Rock

Storm frequency	Peak runoff flow rates	
	cfs	cms
25-year		
2-hour duration	1557	44
6-hour duration	1740	49
24-hour duration	1953	55
100-year		
2-hour duration	1959	55
6-hour duration	2389	68
24-hour duration	2767	78

Source: HRI 1993d.

3.4.1 Regional Roads

Roads of interest in the vicinity of the project sites are shown in Figure 3-12. The roads are maintained by the federal government (I-40 and US 666), the State of New Mexico (NM 371 and 566), and the Navajo Nation (Navajo 9, 49, and 11). Primary access to the region is from I-40, which is a major east-west transportation corridor that runs from Barstow, California to Greensboro, North Carolina. I-40 is generally a four-lane, divided highway constructed to full freeway standards with full access control.

Primary access to the Crownpoint site is from I-40, north on NM 371, west on Navajo 9, and southwest on Church Road in Crownpoint. Primary access to the Unit 1 site is from I-40, north on NM 371, west on Navajo 9, and southwest on Navajo 11 (also known as Picnic Road). Primary access to the Church Rock site is from I-40, north on NM 566.

As indicated in Figure 2-6, shipments from the Unit 1 site to the Crownpoint site would travel northeast on Picnic Road, east on Navajo 9, and southwest on Church Road. Shipments from the Church Rock site to the Crownpoint site would travel north on NM 566, east on NM 11/49, north on NM 371, west on Navajo 9, and southwest on Church Road.

NM 371 is a two-lane, paved highway that extends north from I-40 to Farmington, New Mexico. It would be the direct route for hauling chemicals and yellowcake between the Crownpoint site and I-40. The posted speed limit on NM 371 is 55 miles per hour (mph) except in the town of Thoreau where it is 40 mph.

Navajo 9 is a two-lane, paved highway that extends east from US 666 to Torreon, New Mexico. The 2-mile segment between Church Road and NM 371 would be part of the direct route between the Crownpoint site

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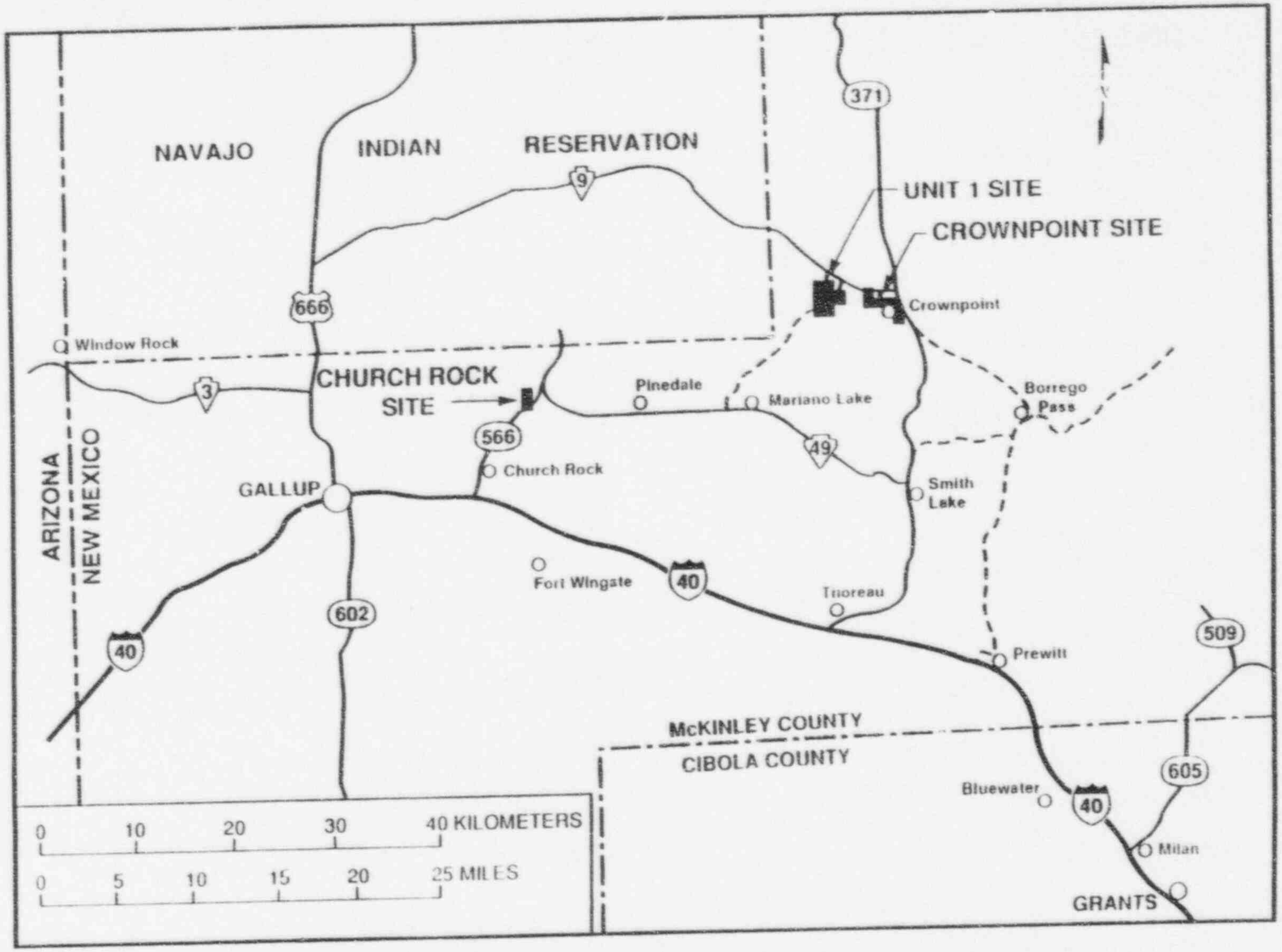

Figure 3-12. Roads in the vicinity of the three project sites.

and I-40. The first mile of Navajo 9 west of NM 371 is multilane and the posted speed limit is 35 mph. The approximately 1.5-mile segment between Church Road and Picnic Road has a posted speed limit of 55 mph.

NM 566 is a two-lane, paved road that extends north 12 miles from I-40. The segment from I-40 to the Church Rock site is the primary access to the site from the south. The approximately 1-mile segment between the proposed Church Rock facility on NM 566 and the junction with Navajo 49/11 would be used to transport yellowcake slurry to the Crownpoint site. The posted speed limit in this segment is 55 mph.

Navajo 11/49 is a two-lane, paved road that extends east 12 miles from NM 566 to the junction of Navajo 11 and 49 just west of Mariano Lake, New Mexico. Navajo 11 (Picnic Road), a two-lane, unpaved road, extends north from the junction to Navajo 9. Navajo 49 extends east from the junction another 12 miles to NM 371. The posted speed limit on NM 11/49 and 49 is 55 mph.

Church Road connects the Crownpoint site with Navajo 9 to the north and provides access to the town of Crownpoint to the east. The east-west segment of Church Road is a two-lane, paved road. Shipments to and from the Crownpoint facility would be over 0.2 mile of paved and 0.5 mile unpaved segments of Church Road. The posted speed limit on Church Road is 30 mph.

3.4.2 Truck Accident Data

The truck accident data presented in this section will be used in Section 4 to determine truck accident frequencies. The total number of truck accidents for the 5-year period 1990–1994 is given in Table 3-25 for each road that HRI would use in the vicinity of the project sites.

Table 3-25. Accident data for roads in the vicinity of the three project sites

Route	Truck accidents 1990–94	Trucks per day	Calculated truck accidents/km	Truck accidents/km used in analysis
NM 371	11	420	3.5E-7	1.4E-6
NM 566	0	209	0	1.4E-6
Navajo 9	2	TBD	TBD	1.4E-6
Navajo 11/49	0	TBD	0	1.4E-6
Church Road	0	TBD	0	1.4E-6

Source: State of New Mexico; Navajo Nation.

The New Mexico State Highway and Transportation Department defines an accident as involving all of the following:

1. involve at least one motor vehicle in motion;
2. occur on a roadway that is open to the public;

3. not occur on private property;
4. involve a death, injury, or property damage over $500; and
5. be reported to the State Highway and Transportation Department on the State's Uniform Accident Report form.

No truck accidents occurred in the 1990–1994 period for several of the routes listed in Table 3-25. A truck accident rate of 1.4E-6/km (2.2E-6/mi) is a widely cited value for two-lane rural roads (Harwood and Russell 1990), and this value will be used both where data are lacking and to ensure a conservative analysis where a lower value is calculated.

The calculated accident rate per trip between the Unit 1 site and the Crownpoint site is 4.2E-6. The distance between the Church Rock site and the Crownpoint site is 1 mile on NM 566, 24 miles on Navajo 49, 14 miles on NM 371, 2 miles on Navajo 9, and 1 mile on Church Road (a total of 42 miles per trip). The calculated accident rate per trip on this route is 5.9 E-5. Between the Crownpoint site and I-40 the calculated accident rate is 3.9E-5.

3.5 ECOLOGY

3.5.1 Regional

Ecological conditions at the three project sites were examined in detail during surveys related to earlier uranium mining developments. Site-specific surveys of the Crownpoint area were conducted for the TVA-Mobil joint venture and published by TVA (1979) and Mobil (1980). SCS (1978) gives a comprehensive review of plant species found in the region.

3.5.1.1 Terrestrial Vegetation

The following discussion of vegetation describes regional conditions, but certain site-specific differences exist among the three project sites.

Within the region, vegetation patterns relate to topography. For example, a broad band of shrub- and herb-dominated vegetation occupies the floodplain that runs diagonally across State Highway 9, approximately 8 km (5 mi) northwest of Crownpoint. Widely scattered piñyon pines or junipers occur on the escarpment just west of the floodplain. Dominant species on the uplands range from annuals to perennial herbs to shrubs.

Grassland vegetation of the central San Juan Basin northeast of the project area grades into pygmy-conifer woodland along the southern edge of the basin. Grasslands predominate on the gently or moderately sloping uplands, with mixed shrub-grass associations on the floodplains and widely scattered pinon-juniper woodland on the escarpments.

Typical grassland sites in the region consist of rolling hills with a few sandstone outcrops. The grassland vegetation is a combination of mixed prairie, grama-galleta steppe, plains and Great Basin grassland, snakeweed grassland, and the alkali sacaton-saltbrush series of the Great Basin region. The most obvious

vegetation elements are grasses, shrubs, and introduced annuals, especially tumbleweed or Russian-thistle (*Salsola iberica*). Blue grama (*Bouteloua gracilis*), alkali sacaton (*Sporobolus airoides*), galleta (*Hilaria jamesii*), squirreltail (*Sitanion hystrix*), and Indian ricegrass (*Oryzopsis hymenoides*) are the most abundant grass species. Mixed with these are a number of subshrubs and shrubs including snakeweed, rabbitbrush, four-wing saltbush (*Atriplex canescens*), and pale wolfberry or desert-thorn (*Lycium pallidum*). Transitional pinyon pine (*Pinus edulis*) or one-seeded juniper (*Juniperus monosperma*) may be found on sandstone outcroppings. Vegetation in the arroyos is generally dominated by four-wing saltbush, pale wolfberry, western wheatgrass (*Agropyron smithii*), and alkali sacaton. A few arroyos also contain stands of greasewood (*Sarcobatus vermiculatus*).

The Crownpoint and Church Rock areas are utilized as grazing ranges by ranchers for cattle, sheep, and other domestic livestock. The characteristics defining a Range Site association include vegetation, topography, soils, elevation, and climate. These characteristics have been developed and presented by the American Ag International (AAI) range specialist (Mobil 1980). Six of the seven range types defined by AAI are found in the project area and are described below.

The loam association is a grassland association found on gently rolling to rolling plains with moderate slopes that are located throughout the project area. Soils are normally deep and well drained with high water-holding capacity. Characteristic plant species found in loam are galleta, blue grama, alkali sacaton, Indian ricegrass, and globe-mallow (*Sphaeralcea* sp.); shrubs and half-shrubs are scattered throughout. The average loam crown cover is 9.5 percent.

Rock outcrop is a grass/shrub association found on gently rolling plains interrupted by rather sharp drop offs at the rock outcrops. Soils are shallow with little development and gravelly surfaces; where vegetated, water permeability is good. Characteristic plant species found in rock outcrops are alkali sacaton, galleta, blue grama, Indian ricegrass, snakeweed, four-wing saltbush, winterfat (*Ceratoides lanata*), shadscale (*Atriplex confertifolia*), and big rabbitbrush (*Chrysothamnus nauseosus*). The average rock outcrop crown cover is 8.5 percent.

Sand-bottomland association is a shrub/grass association of variable composition that is found on very gentle slopes at the base of gently rolling to rolling plains. This association is located on most of the east half of Section 8, Section 15, and the southeast quarter of Section 16. Soils are relatively deep and coarse with high permeability and moderate to low water-holding capacity. As the vegetative cover declines, wind erosion tends to occur. Characteristic plant species found here are greasewood, four-wing saltbush, wolfberry, galleta, Indian ricegrass, alkali sacaton, and squirreltail. Annuals occur seasonally in the sand-bottomland association. The average crown cover is 5.5 percent.

Sandy associations are grass/shrub complexes found on gently rolling or undulating plains of moderate slope (1–10 percent). Soils are deep, coarse textured, and rapidly permeable and have relatively moderate to low water-holding capacity. When the vegetative cover is removed, severe wind erosion can occur. Characteristic plant species found here are galleta, blue grama, Indian ricegrass, squirreltail, little rabbitbrush (*C. viscidiflorus*), snakeweed, greasewood, and big rabbitbrush. Curly dock (*Rumex hymenosepulus*) is an sandy perennial form. The average crown cover in this grass/shrub complex is 16.9 percent.

Bottomland is characterized as a grassland with shrubs or as shrubs with an understory of grasses. It is found in relatively narrow drainages that are periodically covered with water and with slopes between 1 and 3 percent. A tiny area is located at the west edge of Section 16. Soils are usually deep with moderate to high water-holding capacity. Characteristic plant species in bottomland are greasewood, alkali sacaton, and galleta. The average crown cover there is 18.9 percent.

Shallow sandstone, scattered shrubs with an understory of grasses, is found on gently rolling to steep hills, often with sandstone outcrops, exposed veins of coal, and occasional boulders. Soils are shallow with low water-holding capacity. Characteristic plant species found in this range type are juniper, Bigelow sagebrush (*Artemisia bigelovii*), buckwheat (*Eriogonum* sp.), pinyon, and galleta. Other commonly occurring species include alkali sacaton, blue grama, four-wing saltbush, and rabbitbrush. The average crown cover is 17 percent.

3.5.1.2 Terrestrial Fauna

The following discussion of wildlife describes regional conditions, but certain site-specific differences exist among the three project sites.

Mammals. Big game animals are not common in the region. Mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*) occur in the project area, but the preferred habitat of both these big game species is lacking in the immediate vicinity of the project sites.

Mule deer prefer broken landscape and tree cover. The pinyon-juniper vegetation adjacent to the project area is the nearest available mule deer habitat.

In northwestern New Mexico, pronghorns occur in grassland-desert shrub habitat wherever high densities of food can be found. One herd occurs east of Farmington, about 100 km (60 miles) north of the project area, in San Juan County; another is located south of Grants. The State of New Mexico has not reported any pronghorn herds north of Grants in McKinley County. However, it is possible that pronghorns could occasionally wander into the Crownpoint area from their preferred habitats to the north and south.

Mountain lions (*Felis concolor*) have been sighted west of the project area, and black bears (*Ursus americanus*) have been recorded in the highlands south of Crownpoint. Preferred ground cover is lacking in the project area, but, because these predators range over large tracts of land, they may occasionally pass through the area.

Coyote (*Canis latrans*) and kit fox (*Vulpes macrotis*), both of which adapt well to arid conditions, may occur on or near the project sites. Scat similar to that of a coyote was observed, and kit and red foxes (*V. vulpes*) have been sighted southeast of Section 12, T17N R13W. Red fox sighted during mine-area surveys were the first recorded in McKinley County. This species is generally found in more mesic conditions than those represented by the project sites, and its presence is considered accidental. Badgers (*Taxidea taxus*) have not been observed but may occur because the project sites are well within their known range.

Desert cottontails (*Sylvilagus auduboni*) and black-tailed jackrabbits (*Lepus californicus*) are present but not abundant. These animals serve as a prey base for medium-sized and large mammalian carnivores and large avian predators.

A Gunnison's prairie dog (*Cynomys gunnisoni*) town of approximately 50 burrows was identified in the Mobil Crownpoint project area (TVA 1979), but no activity was observed in the town during a summer survey. One prairie dog was observed moving along a perimeter fence some distance from the colony. This lack of activity is highly unusual for an active prairie dog colony, as the young are usually above ground in late May and early June. There have been reports of prairie dog die-offs from bubonic plague in the Crownpoint area. This may explain the discrepancy between an active colony appearing in 1976, but not in 1978.

Small rodents were snap-trapped near Crownpoint in September 1978 and live-trapped and marked in November 1978 and June 1979. The most abundant species were the silky pocket mouse (*Perognathus flavus*) and deer mouse (*Peromyscus maniculatus*).

Avifauna. The most abundant bird in the region is the horned lark (*Eremophila alpestris*). This species is well adapted to areas with low, sparse cover. Songbird diversity, in general, is expected to be very low because of the sparse nesting cover. Waterfowl and shorebirds may pass through the region during migration, and some may use small intermittent ponds or the sewage lagoon near Crownpoint.

Mourning doves (*Zenaidura macroura*) and scaled quail (*Callipepla squamata*) have been observed locally and undoubtedly occur in the project area, although neither species was reported as abundant. Scaled quail are frequently found in arid grasslands, usually nesting on the ground under bushes. Mourning doves are more cosmopolitan, but can also adapt to arid conditions.

The open grasslands of the region provide good hunting areas for raptors. The sandstone escarpment within the project area may provide nesting or roosting sites, and the scattered pinyon pines and junipers could provide refuge. Raptors were not included in the TVA (1979) study, but burrowing owls (*Speotyto cunicularia*) were sighted in Section 12, T17N R13W. The American kestrel (*Falco sparverius*) has been observed nearby and undoubtedly occurs in the project area. Other raptors may also occur in the project area; however, their presence is probably occasional, and their density is expected to be low.

Reptiles and Amphibians. Six species of lizards were seen on or near Section 12, T17N R13W (HRI 1992a) and are very likely to occur in similar habitats elsewhere in the project area. Four snake species were also observed near the project area, including a western rattlesnake (*Crotalus viridis*). Additionally, HRI's (1992a) analysis indicates the presence of the Western spadefoot toad (*Scaphiopus hamondi*). This species is usually found in the sandy soil area of arroyos or floodplains, and a few shallow, incised arroyos are found in the project area.

3.5.1.3 Aquatic Biota

No permanent aquatic habitat exists in the project area that would provide stable conditions for supporting aquatic life. All surface drainages traversing the project area are ephemeral. Similarly, all surface runoff observed in the project area is derived from short, intense rainfall events and quickly percolates into the soil. All stock ponds are temporary and normally dry out after a few weeks.

3.5.1.4 Endangered, Threatened, and Other Special-Status Species

The following description provides background information regarding plant and animal species that have been afforded protected status by federal law and are known to occur in the region or in habitats similar to those found in the project sites. The information on federally listed threatened and endangered species was provided by the FWS (Fowler-Propst 1994). There is no designated critical habitat for federally listed species in the project sites. Species of concern in the State of New Mexico that could occur on the project sites are also discussed briefly.

Federally Endangered Species. The black-footed ferret (*Mustela nigripes*) is usually found in association with prairie dog towns in grassland plains and surrounding mountain basins up to 3200 m (10,500 ft) elevation. A survey for black-footed ferrets is required if a prairie dog town is present and larger than 32 ha (80 acres) for black-tailed prairie dogs or 80 ha (200 acres) for white-tailed and Gunnison's prairie dogs. If the prairie dog town is larger than 400 ha (1000 acres), the area should be evaluated for possible reintroduction of black-footed ferrets.

There are no active prairie dog towns reported in the project area. The Gunnison's prairie dog town with approximately 50 burrows in Unit 1 was reportedly unoccupied in 1978. A site visit in 1995 confirmed the absence of activity. It is therefore unlikely that any black-footed ferrets occur in the project area.

The Southwestern willow flycatcher (*Empidonax trallil extimus*) inhabits thickets, riparian woodlands, pastures, and brushy areas. The project area does not contain preferred habitat for this species, which is not currently known to exist in or frequent the project sites.

The American peregrine falcon (*Falco peregrinus anatum*) prefers areas with steep (e.g., more than 60 m) rocky cliffs near water. No such habitat is present in the project area, so the species is unlikely to occur there.

Federally Threatened Species. The bald eagle (*Haliaeetus leucocephalus*) occupies New Mexico primarily as a winter resident, but also occurs as a migrant with several nesting pairs in the state. Bald eagles roost in large trees, which may or may not be close to their feeding areas. Bald eagles are found in riparian areas adjacent to rivers, reservoi and ponds. Rabbits, fish, and waterfowl are their primary prey. The lack of permanent water in the projec ea should preclude the presence of the bald eagle, and there had been no confirmed sightings of the bird in McKinley County as of 1978 (Hubbard et al. 1978).

The Mexican spotted owl (*Strix occidentalis lucida*) has a range that includes the project area. A recovery plan for the species was released in 1995 (FWS 1995). The spotted owl is found in suitable forested habitat (e.g., closed canopy forest in canyons and riparian zones) in northern Mexico and the southwestern United States (Arizona, Colorado, New Mexico, Texas, and Utah). Because the spotted owl requires timbered habitat, none of which occurs within miles of the project area, it is highly unlikely to occur in the project area.

The Zuni (rhizome) fleabane (*Erigeron rhizomatous*) is often found in close association with Chinle Shale and Baca Formation outcrops with elevations of 2225 to 2400 m (7300 to 8000 ft) in the Zuni, Datil, and Sawtooth Mountains. The preferred habitat for this species consists of sandstone slopes and clay banks. This species was not listed in HRI's analysis of plants noted for the project area (HRI 1988, 1989a,

1992a). The likelihood of this plant species being present is significantly reduced because the project area is below an elevation of 2100 m (6900 ft) and neither the Chinle Shale nor Baca Formation crop out in the project sites.

Federal Species of Concern (Formerly Category 2 Candidate Species). The following Species of Concern are not likely to occur frequently or at all in the project area, primarily because the project sites are at elevations too low to provide the species' preferred habitats.

The occult little brown bat *(Myotis lucifugus occultus)* is a montane dweller and roosts in natural caves, mine tunnels, hollow trees, or buildings. The spotted bat (*Euderma maculatum*) is found in several national forests in New Mexico. This species usually occurs in remote areas, selecting specialized roosting sites near streams and cliffs or steep hillsides with loose rocks. The northern goshawk (*Accipiter gentilis*) primarily uses moderately to highly canopied mature coniferous forests with minimal understory. Nest sites are found in forest stands with a high density of large trees and closed canopy. The ferruginous hawk (*Buteo regalis*) is found almost statewide during migration. Birds seem to favor wide, open grasslands and prairies, especially for nesting. Although the ferruginous hawk could pass through the region, the project sites contain neither high quality habitat nor sufficient game species and land area essential for this hawk.

The Zuni Mountain sucker (*Catostomus discobolus yarrowi*) inhabits small streams, preferring a rock rubble substitute in New Mexico. Morphometric and biochemical methods demonstrate that the Zuni Mountain sucker is the product of hybridization between the Colorado River mountain sucker and the Rio Grande mountain sucker (Smith et al. 1983). It is found in Redosenit Creek, Dean Creek, Rio Nutrias, Rio Pescado, and Zuni River in McKinley County, New Mexico.

The Acoma fleabane (*Erigeron acomanus*) is a mat-forming perennial wildflower. It grows in sandy soils at the base of sandstone cliffs. Associated plant species include one-seeded juniper, pinyon pine, hairy golden aster (*Chrysopsis villosa*), and mountain mahogany (*Cercocarpus montenus*). The Sivinski fleabane (*Erigeron sivinski*) is a perennial with a thick taproot and numerous, short, upright branches. Known only in McKinley County (Zuni Mountains) at elevations from 2130 to 2450 m (7300 to 8000 ft), this species occurs in association with Chinle shale outcrops in selenium-bearing soils.

State-listed Species. The New Mexico Heritage Program lists additional plant species from McKinley County that are considered sensitive. These are *Astragalus fucatus*, found on sand dunes; *Penstemon lentus*, associated with pinyon-juniper woodlands; *Penstemon comarrhenus*, which has not been collected since 1935; *Mitella pentandra*, collected 13 km (8 mi) southeast of Crownpoint at the head of Long Canyon on the mesa rim; *Clematis hirsutissima arizonica*, found in the Zuni Mountains along the roadside; *Carex elynoides*, found 6.5 km (4 mi) north-northeast of Prewitt on gray shale and powdery soil at 3750 m (6800 ft); and *Aletes sessiliflorus*, also 6.5 km (4 mi) north-northeast of Prewitt on top of a sandstone bluff.

Most of these species are typical of the pinyon-juniper vegetation type and occur at elevations higher than those found in the project area. Sparse pinyon-juniper vegetation is found only along the southern edges of the Unit 1 site. As a result, it is unlikely that any of these plant species would be found in the proposed well field areas. *S. mesae-verdae* is found on barren mesas at lower elevations than the project area and, as yet, has not been found as far south as McKinley County. *M. pentandra*, *C. elynoides*, and *A. sessiliflorus* are

found on bluffs and mesas. These plant species might occur on sandstone escarpments in the project area but not in the three project sites.

3.5.2 Crownpoint

3.5.2.1 Terrestrial Vegetation

The Crownpoint site exhibits vegetation communities similar to those discussed for the region (Section 3.5.1.1). Within the site, a variety of vegetation types exists dependent on soil and moisture conditions.

3.5.2.2 Terrestrial Fauna

Wildlife characteristics of the Crownpoint site are similar to those discussed for the region (Sections 3.5.1.2, 3.5.1.3, and 3.5.1.4).

3.5.3 Unit 1

3.5.3.1 Terrestrial Vegetation

The Unit 1 site exhibits vegetation communities similar to those discussed for the region (Section 3.5.1.1). Within the site, a variety of vegetation types exists dependent on soil and moisture conditions.

3.5.3.2 Terrestrial Fauna

Wildlife characteristics of the Unit 1 site are similar to those discussed for the region (Sections 3.5.1.2, 3.5.1.3, and 3.5.1.4).

3.5.4 Church Rock

3.5.4.1 Terrestrial Vegetation

The Church Rock site exhibits vegetation communities similar to those discussed for the region (Section 3.5.1.1). Within the site, a variety of vegetation types exists dependent on soil and moisture conditions.

In the Church Rock area, sagebrush-grasslands predominate up to elevations of 2100 m (6900 ft). Vegetation patterns have been greatly influenced by overgrazing, primarily by sheep. Cattle, goats, and horses also graze the area. At most locations all palatable plant species have been cropped close to the ground and completely eliminated in many areas. Large patches of bare ground are common, and many areas are severely eroded. Conversely, unpalatable subshrubs and shrubs, principally snakewood (*Gutierrezia* spp.) and slenderleaf rabbitbrush (*Chrysothamnus greenei* var. *filifolius*), are abundant. The vegetative cover generally ranges from 2 to 20 percent, sporadically reaching 40 percent.

3.5.3.2 Terrestrial Fauna

Wildlife characteristics of the Church Rock site are similar to those discussed for the region (Sections 3.5.1.2, 3.5.1.3, and 3.5.1.4).

3.6 LAND USE

3.6.1 Regional

The three project sites are located in McKinley County, New Mexico, which is largely rural and consists mostly of open range grazing land and areas used for timber and crop production. McKinley County is the sixth largest county in the state, comprising approximately 14,000 square kilometers or 1.4 million ha (5500 square miles; 3.5 million acres).

Of the nearly 1.4 million ha (3.5 million acres) in McKinley County, over 85 percent [1.2 million ha (3 million acres)] is used for agricultural purposes. Agricultural uses include livestock grazing (sheep, cattle, goats, and horses), forestry (timber production), and crop production. Livestock grazing is the predominant agricultural land use with 1 million ha (2.7 million acres), while timber production is second with 105,000 ha (260,000 acres). In contrast, irrigated and dry crop land occupies only 7100 ha (17,640 acres).

Extractive land uses, primarily coal and uranium mining, account for less than 1 percent of the total land area in McKinley County. Although coal mining has been ongoing in the county since the 1880s, and uranium mining became widespread beginning in the 1950s, the relatively small land areas attributed to these extractive uses can be explained in part by the fact that many of the mining operations involve underground activities that do not affect surface land areas.

Only 0.5 percent of McKinley County's total land area is used for urban land uses (i.e., characterized by various kinds of concentrated residential areas with single- and multi-family dwellings and mobile home parks, commercial districts, and municipal facilities). The county's population is concentrated in the urban areas in and around Gallup.

3.6.2 Crownpoint

The Crownpoint site is located in Sections 19, 24, and 25, T17N R13W, and Section 29, T17N R12W, on the western and eastern edges of the town of Crownpoint. The site is comprised of mixed private land owned by HRI and others, and would be mined through private minerals operating leases or claimed mineral rights. The Crownpoint lease areas include sections of the town of Crownpoint, and well fields and monitor wells would be found in close proximity to residences. Additionally, several churches serving the Crownpoint community are found along the road that would provide access to the central processing facility and overlying ore bodies.

The Crownpoint site covers 365 ha (912 acres), of which approximately 70 percent [255 ha (638 acres)] would be disturbed during project construction and operation. The estimate of 255 ha (638 acres) includes

areas that have been previously disturbed as well as those that would be newly disturbed. Existing processing facilities and settling ponds, which occupy approximately 5.5 ha (14 acres) in the southeastern quarter of Section 24, would be used. Well fields would occupy approximately 205 ha (510 acres). Additional acreage would be required for access roads, on-site wastewater land application areas, and evaporation ponds. If HRI disposes of wastewater using off-site land application, it would occur in Section 12, T17N R13W. Because Section 12 would also be used for land application for the Unit 1 site under this scenario, its 256 ha (640 acres) are included below in the land disturbance calculations for Unit 1. Thus, the total land area that would be disturbed at the Crownpoint site would be approximately 255 ha (638 acres).

3.6.3 Unit 1

The Unit 1 site is located in Sections 15, 16, 21, 22, and 23, T17N R13W, approximately 3.2 km (2 mi) west of the town of Crownpoint. The site is comprised of a block of allotted lands; the mineral and surface rights are owned by Navajo allotees, held in trust and administered by the BIA. The Unit 1 site consists primarily of open range land, although some of the allotted land is occupied by a number of scattered residences, including a traditional Navajo family group. The residences consist of small, wooden frame houses or mobile homes. Separate field interviews, conducted by HRI and NRC in July 1993, indicated that there were seven residences occupied by 26 persons in the Unit 1 lease area. There were seven additional unoccupied residences owned by persons who live permanently in Crownpoint or elsewhere. The area is otherwise undeveloped, and provides open range land suitable only for livestock grazing.

Considerable mineral exploration has taken place within the boundaries of the Unit 1 site. Exploratory drilling took place in the area before 1980, and was conducted on a grid of approximately 60 m (200 ft). The drilled areas can still be delineated by observing aerial photographs, and include the inhabited area of the site. Related mineral extraction took place in the early 1980s when Mobil Oil Corporation (Mobil) conducted the Section 9 pilot project less than 1.6 km (1 mi) outside the Unit 1 site.

All the persons living within the Unit 1 site boundaries are Navajo allotees (who own the surface and mineral rights) or their tenants. Leases for both the surface use and mineral rights on this land are administered by the BIA. The BIA and allottees affected by the proposed project have each signed agreements with HRI authorizing mineral leases and surface use of the land for mining activities. All the residences are located outside the areas to be used for uranium recovery during HRI's initial 5-year mine plan.

The Unit 1 site covers 512 ha (1280 acres), of which approximately 70 percent [358 ha (896 acres)] would be disturbed during project construction and operation. The estimate of 358 ha (896 acres) includes areas that have been previously disturbed as well as those that would be newly disturbed. The satellite processing facility's buildings, plant areas, parking lots, and settling ponds would occupy approximately 2.5 ha (6 acres). Well fields would occupy approximately 280 ha (700 acres). Additional acreage would be required for access roads, on-site wastewater land application areas, and evaporation ponds. If HRI disposes of wastewater using off-site land application (i.e., in Section 12, T17N R13W), an additional area of up to 256 ha (640 acres) could be disturbed. Thus, the total land area that would be disturbed at the Unit 1 site ranges from 358 ha (896 acres) (on-site land application) to 614 ha (1536 acres) (off-site land application in Section 12).

3.6.4 Church Rock

The Church Rock site is located in Sections 8 and 17, T16N R16W, approximately 10 km (6 mi) north of the town of Church Rock. The site consists primarily of undeveloped range land. A portion of the site was previously developed with surface facilities for an underground uranium mine, and the site has been only partly restored. A few scattered residences are located within 3 km (2 mi) of the site, but only some of them are inhabited throughout the year.

The Church Rock site covers 145 ha (360 acres), of which approximately 90 percent [130 ha (324 acres)] would be disturbed during project construction and operation. The estimate of 130 ha (324 acres) includes areas that have been previously disturbed as well as those that would be newly disturbed. The satellite processing facility's buildings, plant areas, parking lots, and settling ponds would occupy approximately 2.5 ha (6 acres). Well fields would occupy approximately 32 ha (80 acres). Additional acreage would be required for access roads, on-site wastewater land application areas, and evaporation ponds. If HRI disposes of wastewater using off-site land application (i.e., in Section 16, T16N R16W), an additional area of up to 256 ha (640 acres) could be disturbed. Thus, the total land area that would be disturbed at the Church Rock site ranges from 130 ha (324 acres) (on-site land application) to 386 ha (964 acres) (off-site land application in Section 16).

3.7 SOCIOECONOMICS

The proposed project would be located in McKinley County in northwestern New Mexico. The local communities in the immediate vicinity of the project are located within the borders of the Crownpoint and Church Rock chapters of the Navajo Nation. In the Navajo Nation governmental structure, chapters are the smallest jurisdictions. The Crownpoint and Church Rock chapters are part of the Eastern Navajo Agency, which includes 31 chapters.

The Crownpoint Chapter includes 67,364 acres and had an estimated population of 2,597 in 1993. The Church Rock Chapter includes 52,719 acres and had an estimated population of 1,742 in 1993. Although the towns of Crownpoint and Church Rock are located outside the boundaries of the Navajo Reservation, they are represented in the Navajo Nation, the governing body that provides local public services including water, sewer, social services and police protection.

The Crownpoint and Church Rock chapters are located in the area of McKinley County known as the "checkerboard" for its mixed private tribal and government property rights. Much of the area includes property that is under the Navajo Tribal Trust and individual Navajo allotments that are privately held with some BIA oversight.

3.7.1 Demographics

McKinley County had a population of 60,686 in 1990, and an estimated population of 65,006 in 1995. The county is projected to grow to 69,286 persons by 2000, and to 77,823 by 2010. McKinley County's annual population growth rate between 1980 and 1995 was 0.9 percent, and is projected to be 1.2 percent between

1995 and 2010. This compares to the State of New Mexico's population growth of 1.5 percent and 1.3 percent over the same periods (University of New Mexico 1994).

Recent population increases in McKinley County can be attributed to the increase in Native American population. The Native American population increased by over 6,000 (+11.4 percent) from 1980 to 1990, while the non-Native American population decreased by over 2,000 (-13.0 percent). The percentage of the county's total population comprised of Native Americans was 66 percent in 1980 and 72 percent in 1990 (Table 3-26). Persons of Hispanic origin represented about 13 percent of McKinley County's 1990 population. In 1990, over 70 percent of McKinley County's white population resided in Gallup. Outside of Gallup, 85 percent of the population was Native American.

Table 3-26. 1990 population and racial characteristics of the State of New Mexico, McKinley County, Crownpoint, and Gallup

	Total	White	Black	Indian	Other[a]	Hispanic origin[b]
New Mexico	1,515,069	1,146,028	30,210	134,097	204,734	579,224
(percent of total)[c]		75.6%	2.0%	8.9%	13.5%	38.2%
McKinley County	60,686	13,295	295	43,570	3,526	7,764
(percent of total)		21.9%	0.5%	71.8%	5.8%	12.8%
Crownpoint (Census Designated Place)	2,108	153	12	1,929	14	28
(percent of total)		7.3%	0.6%	91.5%	0.7%	1.3%
Gallup city	19,154	9,544	223	6,363	3,024	4,185
(percent of total)		49.8%	1.2%	33.2%	15.8%	21.8%
McKinley County not including Gallup	41,532	3,751	72	37,207	502	3,579
(percent of total)		9.0%	0.2%	89.6%	1.2%	8.6%

[a]Other includes Asian and Pacific Islander.

[b]Hispanic origin can be any race and is calculated as a separate component of the total population (i.e., if added to the other 3 racial cohorts the total will be more than 100%).

[c]Percentages do not add to 100 because of rounding and because "Hispanic origin" is not a racial category.

Source: U.S. Bureau of the Census 1990.

The town of Crownpoint has also experienced rapid population growth recently, doubling in size from 1980 to 1993. Between 1980 and 1993, Crownpoint's population growth averaged 5.5 percent annually, compared to that of the Church Rock Chapter (0.6 percent annually from 1980 to 1993) and Gallup (0.5 percent annually from 1980 to 1990). This rapid population growth in Crownpoint is partially explained by improved access to the town with the completion of the fully paved State Highway 371. Also, Crownpoint is the "agency" town for the Eastern Navajo Agency and, as such, is a key center for Navajo Nation social services for the surrounding area. Crownpoint's population growth in the 1980s can also be attributed, in part, to the addition of a new hospital, high school, and shopping center. During this period of rapid growth, the Navajo Nation Governmental offices were expanded and an airport was built approximately 6 kilometers (3.7 miles) west of the community (Rodgers 1993).

3.7.2 Income

Tables 3-27 and 3-28 present income characteristics for the residents of McKinley County by race. The tables indicate that McKinley County is relatively poor compared to the rest of the state. Although the county's per capita income increased from $6,148 in 1984 to $9,668 in 1990, the number of residents living in poverty also increased from 20,773 in 1979 to 26,118 in 1989 (U.S. Bureau of the Census 1994). The number of residents below the poverty level in 1989 represented about 43.5 percent of McKinley County's population, compared to about 20.6 percent for the state (U.S. Bureau of the Census 1994).

Table 3-27. McKinley County household income distribution by race

Income interval ($)	White (%)	American Indian (%)	Other Race (%)
0 to 4,999	2.2	16.4	0.5
5,000 to 9,999	2.3	10.1	1.1
10,000 to 14,999	2.9	8.1	0.9
15,000 to 24,999	6.1	11.8	1.6
25,000 to 34,999	6.1	7.0	1.2
35,000 to 49,999	6.2	4.4	1.1
50,000 to 74,999	4.1	1.9	0.4
75,000 to 99,999	1.3	0.8	0.3
Above 100,000	0.8	0.1	0.2
Percent of all households	32.0	60.6	7.4

Source: U.S. Bureau of the Census 1990.

As Tables 3-27 and 3-28 indicate, McKinley County's Native American population makes up a disproportionate number of its poorest residents. The Native American poverty rate is about five times that of the white population in McKinley County. According to 1990 Census data, about 27 percent of the Native American households had incomes below $5,000 and about 24 percent had incomes above $25,000. The comparable figures for white households in 1990 were 7 percent and 58 percent, respectively.

3.7.3 Earnings and Employment Structure

McKinley County has a relatively high unemployment rate. In August 1995, McKinley County's unemployment rate was 8.3 percent, compared to 6.4 percent for New Mexico and 5.6 percent for the U.S. By July 1996, McKinley County's unemployment rate had increased to 10.9 percent, compared to 7.5 percent for New Mexico and 5.1 percent for the U.S. McKinley County's July 1996 unemployment rate indicates a significant decline in the regional economy. The Native American labor force generally suffers from higher unemployment rates than the total labor force. For example, in 1990 the total unemployment rate for McKinley County was 13.6 percent, with Native American unemployment at 15.5 percent and non-Native American unemployment at only 6.7 percent.

Government employment is the single largest source of jobs (about 19 percent of wage and salary employment in 1994) and earnings (about 31 percent of total county earnings in 1990) in McKinley County (U.S. Bureau of the Census 1994). Other types of employment that are important to McKinley County's

Table 3-28. Comparison of income and poverty status in 1989 between McKinley County and the State of New Mexico

	New Mexico	McKinley County
Per capita income	$11,246	$6,628
Median household income	$24,087	$17,468
Per capita income by race		
White	$12,673	$13,780
Black	$8,579	$15,865
American Indian, Eskimo, or Aleut	$5,141	$4,094
Asian or Pacific Islander	$10,655	$17,075
Other race	$7,320	$9,496
Percent below poverty level--all persons	20.6%	43.5%
White	16%	11%
Black	26%	27%
American Indian, Eskimo, or Aleut	45%	54%
Asian or Pacific Islander	17%	0%
Other race	29%	34%

Source: U.S. Bureau of the Census 1990.

economy include the health care professions, coal mining, timber milling, jewelry manufacturing and wholesaling, and elementary and secondary education (U.S. Bureau of the Census 1995).

In 1990, the goods-related industry (including mining, manufacturing, and construction) represented a higher proportion of total county earnings (20.5 percent) than it did for total state earnings (17.4 percent). However, manufacturing wages in McKinley County averaged only $13,000 per year compared to the New Mexico average of $25,000 per year.

Agriculture is another source of employment and earnings in McKinley County. In 1987, there were 240 farms in the county with an average value of products sold of about $38,000. Farm population in 1990 was 568, with farm earnings of about $5 million (about 1.2 percent of total county earnings).

These agricultural statistics do not, however, capture the economic significance of subsistence agriculture in McKinley County, as common activities such as gardening and livestock grazing are not included under employment, earnings, or income. Conversely, the adverse effects of livestock grazing indicate the importance of subsistence agriculture in the Navajo areas of McKinley County. According to the May 24, 1996 *Gallup Independent*, Navajo Nation President Albert Hale indicated that overgrazing was one of the primary factors making existing drought conditions worse. Referring to temporary solutions such as emergency feed and water for livestock, he said:

> "They didn't get at the basic problem, which is overgrazing . . . You only need to look at the land outside the right-of-way fences to see how well vegetation can survive despite the drought . . . Inside the fences, the land needs to rest for years . . . Hopefully, the livestock owners will understand what

we're trying to do when they see what is happening to the land . . . There's just too much livestock on the land."

Tourism is also very important to McKinley County's economy. There are many attractions in and around Gallup, including the Hubbell Trading Post National Historic Site, ceremonial Indian dances, and retail outlets for jewelry and rugs. Crownpoint is well known for its periodic rug auctions and is the last chance for food and fuel on the way to the Chaco Culture National Historic Park via I-40. The Chaco Culture National Historic Park includes displays of Chacoan trade goods, pottery, turquoise, and jewelry, and has about 80,000 visitors annually (Van Dyke 1996a).

The town of Crownpoint's main economic activity is education, with three schools that had a total combined enrollment of over 1,400 in 1992. These schools include a public elementary school with an enrollment of about 400, a public high school with an enrollment of about 600, and a BIA-operated Indian boarding school with an enrollment of about 400. The two public schools are run by the State of New Mexico and have both Native American and non-Native American enrollment. The town of Crownpoint also has several small parochial schools and the Crownpoint Institute of Technology. There are several retail and service businesses in Crownpoint, including convenience stores, gas stations, a restaurant, two laundromats, a video store, a super market, and a rug cooperative which has periodic rug sales. Table 3-29 lists the largest employers in Crownpoint.

Table 3-29. Major employers in Crownpoint

Employer	Number of employees
Navajo Nation	455
Bureau of Indian Affairs	350
Indian Health Services	248
Gallup-McKinley County Schools	200
C.I.T.	75
Bashas (Supermarket)	35
Navajo Housing Authority	11
Thriftway	6
Crownpoint Country Store	4
Navajo Communications Company	3

Source: Rodgers 1993.

Because the Eastern Navajo Agency is headquartered in Crownpoint, several Navajo governmental functions are located there, including an Indian hospital. However, despite the various governmental activities, Crownpoint per unit housing value is only 25 percent of that in Gallup, reflecting the lower incomes of the predominantly Native American population. The relative lack of retail businesses in Crownpoint given the town's population may reflect (1) policies of the Navajo Nation that discourage

businesses (Van Dyke 1996b) and/or (2) consumer preferences for shopping in larger cities and (3) relatively low expendable income.

Retail establishments in Church Rock include a gas station, two convenience stores, a restaurant, a trading post, and a laundromat. The major employers in Church Rock include local schools (57 employees), the Meridian Oil Company (39), Hamilton Construction Company (25), Indian Plaza (18), and the Red Rock State Park (17). There are also about 40 to 50 family farms in the area.

3.7.4 Housing and Public Infrastructure

3.7.4.1 Housing

Table 3-30 presents a comparison of housing statistics for Crownpoint, Gallup, McKinley County, and the State of New Mexico. There is a significant difference in the value of housing in Gallup compared to the rest of McKinley County, reflecting the higher incomes of residents in Gallup.

Table 3-30. Households, housing, and rent in McKinley County

	Crownpoint	Gallup Division	McKinley County	New Mexico
Total housing units	1,911	7,471	20,933	632,058
Median value owner-occupied housing	$14,999	$67,300	$40,700	$70,100
Median contract rent	$158	$276	$221	$312
Occupied housing units (households)	1,339	6,832	16,588	542709
Vacant housing units	572	1,725	4,345	89,349
Percent vacant	30%	23%	21%	14%
For Season, recreational, or occasional use	65	926	940	21,862
Owner-occupied	864	4230	11700	365,965
Percent owner-occupied	45%	57%	56%	58%
Renter-occupied	475	2,602	4,888	176,744
Percent renter-occupied	25%	35%	23%	28%
Aggregate value of owner- occupied housing	$9,011,500	$201,167,000	$354,459,000	
Average value of owner- occupied houses	$10,430	$47,557	$30,296	
Average value of owner-occupied houses for McKinley County outside Gallup—$20,521				
Persons per occupied housing unit	1.57	3.11	3.66	2.79
Persons per occupied housing unit for McKinley County outside Gallup—4.04				

Source: Bureau of the Census 1990.

Although the official vacancy rate in McKinley County is high (Table 3-30), local sources indicate that housing availability is very limited (Van Dyke 1996b; 1996c). This inconsistency between Census data and individual assessments is probably due to the many vacant dwellings in the county that are substandard. In

addition, private land for residential development is very limited in McKinley County due to extensive federal and state land ownership. Some housing, including trailers, is available in the Thoreau area just off Interstate 40 south of Crownpoint. Housing is also quite limited in other parts of McKinley County, including Gallup. Because of the county's lack of available housing, choice is limited and extended waiting periods for housing are not uncommon (Van Dyke 1996b; 1996c).

3.7.4.2 Water and Waste Water Services

Water and waste water services for Crownpoint residents are provided by the Navajo Tribal Utility Authority (NTUA). NTUA serves 776 water customers and 575 waste water customers. Three NTUA water supply wells in Crownpoint provide 90.6 million gallons per year. Approximately 300,000 to 500,000 barrels per year are hauled to surrounding areas at a price of about $0.50 per barrel. NTUA could supply additional customers with water, but waste water service is limited because of the difficulty in attaining land for expanding treatment facilities. The alternative for new residential development is septic tanks (NTUA 1996).

The Church Rock community has a water and waste water system with adequate capacity for expansion. The community's water supply well is completed to a different formation than the town of Crownpoint's and is located about five miles south of the Church Rock site (NTUA 1996).

3.7.4.3 Police, Fire, and Emergency Protection

Police protection in the vicinity of the project area is provided by the Navajo Nation. According to the Northwest New Mexico Council of Government Deputy Director, police protection in the Crownpoint area may be inadequate with a recent surge in juvenile crime (Van Dyke 1996b).

Fire protection in the area is provided by various volunteer fire departments. There are 20 fire districts in McKinley County; the districts that cover the area of the proposed project are Crownpoint, White Cliffs, Pinedale, and Thoreau. The Crownpoint Volunteer Fire Department consists of 24 volunteers, is funded by McKinley County, and has basic firefighting equipment (Van Dyke 1996d). The Pinedale fire district, which is responsible for the Church Rock area, has 15 members but no formal fire station.

Emergency medical service (EMS) in the project area is provided through a two-tier system. The first tier is a voluntary rescue unit located in and responsible for a specific area. The second tier is a response-by-ambulance service provided through either McKinley County or the Navajo Nation EMS. The voluntary rescue unit includes medical equipment and extraction capabilities.

The Crownpoint Indian Health Care Facility is an ambulatory care hospital with 32 beds serving about 26,000 Navajo in the Eastern Navajo Agency. The hospital provides general and obstetrics care (Van Dyke 1996e).

3.7.4.4 Education Resources

There are a total of 15 public and private schools in the area surrounding the proposed project sites. These include Crownpoint (five schools with over 1,600 students), Church Rock (five schools with over 1,000 students), Mariano Lake (two schools with approximately 245 students), and Smith Lake (two

schools with approximately 120 students). The schools in Crownpoint include a public elementary school with an enrollment of about 400, a public high school with an enrollment of about 600, and a BIA-operated Indian boarding school with an enrollment of over 400. The two public schools are run by the State of New Mexico and have both Native American and non-Native American enrollment. The town of Crownpoint also has several small parochial schools and the Crownpoint Institute of Technology, which is an accredited post-secondary vocational institute with an enrollment of about 300 (Van Dyke 1996f). The Crownpoint Institute of Technology is an important educational resource in providing Navajo with the training necessary to access the skilled labor market.

3.7.5 Taxes and Local Finance

Sources of tax revenue for McKinley County include property and gross receipts taxes. The county's tax rate on real and personal property is $30.823 per $1,000 of assessed value. Assessed value is set at one-third of fair market value. Therefore, the annual property tax on a house on private property with a market value of $70,000 would be approximately $700. Business assets are also classified as personal property, but for tax purposes can be depreciated at various schedules down to a floor of 12.5 percent. Therefore, a piece of equipment with a market value of $1 million when new would generate approximately $60,000 in personal property taxes for the county over a 10 year period assuming a federal tax depreciation schedule of 10 years.

The assessed value of uranium production for tax purposes is 50 percent of the sales price. Therefore, at the current property tax rate McKinley County would collect $15,412 ($1,000,000 × 0.5 × 0.030823) for each million dollars of yellowcake produced and sold (Van Dyke 1996g).

McKinley County can collect property taxes on equipment and improvements for any non-Navajo operation outside the Navajo Reservation. The county can also tax any Navajo Reservation lands that have been acquired as private property. Mining property is taxed at 50 percent of the sales value of the ore. Therefore, if a mining operation sold $1 million of ore per year from privately owned property, the McKinley County tax rate would be applied on $500,000 annually.

McKinley County receives a 0.25 percent gross receipts tax revenue as part of the gross receipts tax on goods and services collected by the State. Although this tax is applied to businesses, it is passed on to customers and resembles a sales tax. With the gross receipts tax, for every $10,000 of purchases made in McKinley County, the county receives $25 from the State.

The Navajo Nation can levy taxes in an area outside the Navajo Reservation if the area is classified as being in "Indian country." Navajo taxes include a 5 percent business activities tax on business gross receipts. Gross receipts are reduced by a 10 percent standard deduction plus deductions for compensation paid to Navajo employees. This tax could be levied on uranium production off the Navajo Reservation if the production is determined to occur in "Indian country". The Navajo business activities tax on construction is a 3 percent tax on payments to contractors and subcontractors without deductions for various construction activities including well drilling.

The State of New Mexico levies a 3.5 percent severance tax and a 0.75 percent natural resources tax on the sales price of uranium.

The town of Crownpoint receives public funding from the federal government, the Navajo Nation, the State of New Mexico, and McKinley County. For example, the Crownpoint Indian Health Care Facility is funded by the federal government, water and waste water services and police protection are provided by the Navajo Nation, and public education is provided by the State of New Mexico and McKinley County.

3.8 AESTHETICS

The primary viewers of the proposed project would be Navajo residents living on and near the three project sites. Because they would be the primary observers, their notion of aesthetic resources as expressed at the landscape scale is important. In general, Native American thought is "integrative and comprehensive. It does not separate intellectual, moral, emotional, aesthetic, economic, and other activities, motivations, and functions" (Norwood and Monk 1987). The Navajo language often combines two or more of these categories:

> The Navajo concept of beauty is expressed in the suffix *-zho-*. This is usually preceded by *ni*, meaning something specific, or *ho*, conditions in general. A beautiful rug is *nizhoni* and a beautiful place is *hozhoni*. Both these terms connote order, good, harmony, health, and happiness. For both the Navajo and Zuni, moral good tends to be equated with aesthetic good: that which promotes or represents human survival and human happiness tends to be experienced as "beautiful." The landscape is beautiful by definition because the Holy People designed it to be a beautiful, harmonious, happy, and healthy place. (Norwood and Monk 1987)

The Navajo language does not contain the word "landscape." Navajos have not created an abstract category for unspecified vistas; the emphasis is on specific mountains, specific trees, and specific colors of the soil rather than on the "Navajo landscape" (Norwood and Monk 1987). Thus, to Navajo readers, references to the visual quality of the study areas may be more meaningful when in reference to an identifiable place, not to generalized landscapes across the study areas. Navajo feel that because the landscape is *the* land that supports life for the Navajo, it is therefore beautiful.

3.8.1 Regional

Aesthetics features of the three project sites were evaluated during field reconnaissance in October 1995. Natural and scenic attractions near the project sites are minimal. Regionally, the Chaco Culture National Historic Park, El Malpais National Monument, El Morro National Monument, the Bisti Wilderness and the Red Rock State Park, among many other features, attract tourists for their aesthetic features as well as for their historic and cultural prominence.

The three project sites are generally visible from the area roads. These roads are used mainly for local travel. There are no regionally—or, particularly locally—important or high-quality views associated with the project sites.

Extant vegetation patterns relate to the topography quite closely. There are widely scattered piñon pines along the higher grounds and escarpment in the study area. Junipers are less plentiful. The three sites are dominated by sparse grasslands, generally severely damaged by overgrazing by sheep and, less frequently,

cattle, horses, and goats. Rolling hills also characterize the study area, often punctuated by sandstone outcrops. Lower floodplains have mixed shrub-grass associations, with the arroyos having saltbush and some greasewood (see Section 3.5).

3.8.2 Crownpoint

The more urban character of the Crownpoint area dominates the aesthetic values at the Crownpoint site. The presence of the existing HRI facilities and the nearby churches, residences, and other structures reflect the area's small New Mexican town appearance. The evaporation ponds, chain link fences, parking lots, and metal HRI buildings give a low-intensity industrial appearance to eastern portions of the Crownpoint site. Because of overgrazing in many areas in the past, bare soil and erosion are commonplace. The sandstone outcrops, on the other hand, provide a most natural-looking character to some of the area. Views to the west are the best on the site. These look out over rolling hills toward the Unit 1 site, over an intervening arroyo, with distant mountains in the background.

3.8.3 Unit 1

Unit 1 is the most natural appearing of the three sites. The area is characterized by rolling grass-covered hills used for sheep grazing, small arroyos, and scattered piñon trees. Rock outcrops are few and access by vehicle is on an unpaved road. Because of overgrazing in many areas in the past, large patches of bare soil and erosion are commonplace. Grass is cropped closely to the ground. Vegetative cover for the project area ranges from only two to eight percent, occasionally covering an extent of ten to twelve percent. Some evidence of past habitation (old foundations, potsherds) is visible. Views are best to the south, with an immediate ridge providing some enclosure to the otherwise open, undistinguished site. The unpaved road to Route 49 provides some higher-elevation views back to the Unit 1 site as it ascends an intervening saddle.

3.8.4 Church Rock

The Church Rock site has been overgrazed by cattle more than sheep. It is characterized by a large, shallow, grassland valley between two large sandstone bluffs. The area is entirely consistent with the greater regional landscape and well integrated into it. Evidence of past deep mining for uranium exists, with a metal utility building in good condition on the west end of the site. There is a large concrete pad for the shaft for the old mine. Platforms for past exploratory drilling are visible, but are only slightly incongruous with the general landscape. Temporary drill-site markers (< 1m tall) punctuate the potential mining areas. The best views are from the northern portion of the site where one can look down-valley and out toward a distant mountain range. The views from the western bluffs are also higher quality as one looks toward the proposed mining areas in the valley to the southeast. The views from the road up the project site are of lower quality.

3.9 CULTURAL RESOURCES

3.9.1 Regional

This section discusses the history of human habitation in the region in which the three project sites are located. More detailed information is provided in Appendix B. The information serves as background material for the cultural resources, socioeconomic, and environmental justice assessments in this EIS, since all three categories of human activity are founded on the same fundamental cultural underpinnings.

Much of the American Southwest, in general, and the Crownpoint region, in particular, stands out from the rest of the country because of the combination of ethnic groups that predominate in the area: Native American, Hispanic, and Anglo. To understand the modern human environment, it is essential to understand the role of these groups in the region. History and prehistory continue to have a very real influence on the lives of these citizens even today. Native American culture and resources are emphasized in this section because Native Americans own or have been allotted the land proposed by HRI for uranium mining, and remaining cultural resources overwhelmingly are from Native American cultures.

For purposes of this EIS, the National Park Service definition of "culture" found in Bulletin 38, *Guidelines for Evaluating and Documenting Traditional Cultural Properties*, will be used. It states:

> in the National Register [of Historic Places] programs the word is understood to mean the traditions, beliefs, practices, lifeways, arts, crafts, and social institutions of any community, be it Indian tribe, a local ethnic group, or the people of the nation as a whole (Parker and King n.d.).

Cultural resources are objects, structures, locations, or natural features that reflect the culture of some group of humans. Such resources are potentially eligible for inclusion on the National Register of Historic Places (NRHP) if they meet criteria set forth in 36 CFR 60.4 as follows:

> The quality of significance in American history, architecture, archeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and that (a) are associated with events that have made a significant contribution to the broad patterns of our history; or (b) that are associated with the lives of persons significant in our past; or (c) that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant distinguishable entity whose components may lack individual distinction; or (d) that have yielded or may be likely to yield information important in history or prehistory.

Varying degrees of federal protection and appropriate management procedures are set forth in several U.S. statutes and their amendments, including the National Historic Preservation Act of 1966, as amended through 1992, 16 U.S.C. §§ 470–470w-6 (1982); the Archeological and Historic Preservation Act of 1974, 16 U.S.C. §§ 469–469c (1982); the Archaeological Resources Protection Act of 1979, 16 U.S.C. §§ 470aa–470mm; and the Native American Graves Protection and Repatriation Act, 25 U.S.C. §§ 3001–3013.

Three categories of cultural resources are of interest in the NEPA process: archaeological, historical, and traditional cultural resources. Such resources are considered to be "cultural properties" when their significance is deemed by professionals to make them eligible for inclusion in the National Register. Such eligibility or inclusion requires that any Federal agency contemplating some action consider the potential for adverse impacts to such a cultural property. The three categories of cultural property are defined below.

An archaeological property is an archaeological resource that is eligible for inclusion on the National Register as specified above. An archaeological resource is defined in the Archaeological Resources Protection Act of 1979 and 16 U.S. Code §§ 470bb as:

> Any material remains of past human life or activities which are of archaeological interest, as determined under uniform regulations promulgated pursuant to this Act. Such regulations containing such determination shall include, but not be limited to: pottery, basketry, bottles, weapons, weapon projectiles, tools, structures or portions of structures, pit houses, rock paintings, rock carvings, intaglios, graves, human skeletal materials, or any portion or piece of any of the foregoing items. Nonfossilized and fossilized paleontological specimens, or any portion or piece thereof, shall not be considered archaeological resources, under the regulations under this paragraph, unless found in an archaeological context. No item shall be treated as an archaeological resource under regulations under this paragraph unless such item is at least 100 years of age.

The term "historic property" is defined as "any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register. The term includes artifacts, records, and remains that are related to and located in such properties (Advisory Council on Historic Preservation 1986).

A traditional cultural property can be defined as a property "that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that (a) are rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community (Parker and King n.d.)." The authors of this definition, which is the basis for the guidelines for evaluating such properties, recognize the vagueness in the definition and provide the analyst with further assistance:

> Traditional cultural properties are often hard to recognize, however. A traditional ceremonial location may look like merely a mountaintop, a lake, or a stretch of river; a culturally important neighborhood may look like any other aggregation of houses, and an area where culturally important economic or artistic activities have been carried out may look like any other building, field of grass, or piece of forest in the area. As a result, such places may not necessarily come to light through the conduct of archeological, historical, or architectural surveys. The existence and significance of such locations often can be ascertained only through interviews with knowledgeable users of the area, or through other forms of ethnographic research. The subtlety with which the significance of such locations may be expressed makes it easy to ignore them; on the other hand it makes it difficult to distinguish between properties having real significance and those whose putative significance is spuric

Because of the difficulty in distinguishing and evaluating traditional cultural properties, it is essential to involve in the assessment both traditional practitioners, who make use of such resources, and trained professionals, who can make an independent assessment of their importance.

It should be noted that simply because a property from any of these three categories is eligible for or is on the National Register does not mean it must be protected from destruction. Rather, it means that federal officials must consider the property in any federal or federally-assisted or regulated action. If a public interest justifies a property's destruction, it can be destroyed.

The following discussion is intended to provide a broad overview of human development in the project region. Data that are specific to the three project sites are almost nil, except for data that have been produced from the cultural resources surveys conducted to date, primarily in conjunction with this project. As a result the prehistory and history of the three sites must be inferred to a great extent from the broader regional history. Such regional history may be as general as the "Southwest" or as narrow as the "San Juan Basin" or the "Four Corners." To facilitate discussion, the section is divided into two major time periods: 10,000 B.C. to 1540 A.D. and 1540 to present. The year 1540 was the date of Franciso Coronado's expedition in search of the legendary Seven Cities of Cibola and marks the beginning of contact between the region's Native Americans and Europeans and of profound changes in its history and culture.

3.9.1.1 Pre-contact (10,000 B.C. to 1540 A.D.)

Paleo-Indian and Archaic Periods

The prevailing view among archaeologists is that early Americans are thought to have migrated into what is now the American Southwest by 10,000 B.C. This date must be viewed as establishing only a very approximate time-frame, as what little physical evidence that exists is hard to date. Human settlement in the Southwest appears to have been influenced greatly by climatic conditions, with wetter periods generally being more conducive to increased populations. In fact, the archaeological record is quite sparse for the older half of this period, implying dramatic ebbing and flowing of human populations, quite possibly in response to parallel changes in game populations (Woodbury 1979; Irwin-Williams 1979).

The Paleo-Indian period was comprised, successively, of the Clovis, Folsom, and Cody cultures, the last of which came to an end around 6,000 B.C. Human populations during this extensive period were mobile and followed the herds of large mammals, such as mammoth, horse, and camel, which provided them with most of their subsistence (Irwin-Williams 1979). It is believed that these early populations ultimately left the Southwest entirely, perhaps as a result of changing climatic conditions.

The Archaic period succeeded the Paleo-Indian, lasting from around 6,000 B. C. to about 400 B. C. With the larger mammals extinct, humans of the Oshara culture, as it was called in the Southwest, hunted bison, deer, and smaller mammals and gathered seeds and plants for their subsistence. Gradually, human populations began to settle in more permanent locations, and there is evidence of primitive attempts to cultivate corn and squash.

The archaeological surveys completed for the three project sites have discovered no artifacts from the Paleo-Indian or Archaic periods. This does not mean that humans from these periods did not live in or traverse the Crownpoint area. Rather it reflects the probability that sparse populations, the meagerness of

human belongings, and the actions of the elements on rather fragile artifacts over many thousands of years militate against finding sites from the Paleo-Indian and Archaic periods without archaeological excavation.

Basketmaker II–III

The Basketmaker cultures followed the Archaic period in the Four Corners region and lasted until about 700–750 A.D. Human populations became much more sedentary than in previous periods, living often in small settlements of semi-buried pithouses under large rock overhangs. They wove baskets, clothing, and many other personal goods out of fibers (from which their name is derived), grew much of their own food, and hunted game (Ferguson and Rohn 1987). Continuing human development led to the Basketmaker III culture, beginning about 400 A.D. It was characterized by "pithouse villages, ceramics, the bow and arrow replacing the atlatl and dart, domesticated turkeys, a developing agriculture, and some large structures that are the prototypes of the later great kivas of the Anasazi (Ferguson and Rohn 1987)." A complex trade in marine shells and pottery with Mexico and the Pacific Coast appears to have existed.

Basketmaker III sites have been found at the Crownpoint and Unit 1 sites, and perhaps the Church Rock site as well. Artifacts include pithouses, stone slab circles, hearths, several masonry rooms, potsherds, and lithic scatter. Detailed descriptions are found below and in Marshall 1989, 1991, 1992, and Klager 1979. Marshall (1991) believes there is evidence of the Basketmaker II culture in the form of a hearth and lithic scatter at the Unit 1 site. If so, this site would be the oldest site identified at the three project sites.

Anasazi[1]

The Anasazi culture is divided into three periods with the approximate dates of Pueblo I, 700–900; Pueblo II, 900–1100; and Pueblo III, 1100–1300 (Woodbury 1979). As a generalization, the Anasazi culture advanced progressively through these periods with social organization, architecture, irrigation, horticulture, pottery, trade, and communications all becoming more developed. Settlements became larger and residential quarters changed from the semi-underground Basketmaker III structures to the above-ground, small units of the Pueblo I period, finally culminating in the large, masonry structures called pueblos (after the Spanish word for village) in the Pueblo II and III periods.

It is the surviving architectural monuments of the Pueblo II and III periods that have created so much interest in, and recognition of, Anasazi culture. Spruce Tree House and Cliff Palace in Mesa Verde and Pueblo Bonito in Chaco Canyon are the more spectacular of these structures and inspire much awe in modern Americans and constitute, in the minds of many people, the most impressive archeological sites in the United States. The large, 3–4 storied structures constructed over several generations that feature extraordinary masonry, siting that takes advantage of natural heating and cooling regimes, oftentimes unique topographic placement to maximize defensibility, and large circular structures called kivas for cultural activities are true monuments to their builders who possessed only stone tools, knew nothing of the wheel, and were illiterate (except for rock art) (Ferguson and Rohn 1987). In addition, the Anasazi built substantial irrigation systems that captured periodic storm runoff in side canyons for diversion and use on

[1]The name Anasazi originates from the Navajo, which today is popularly translated as "the ancient ones" but is more accurately translated as "ancient enemies" (Holt). For their part, the Hopi and Zuni, who claim direct ancestry to the Anasazi, use the names *Hisatsinon* and *Enote*, respectively for Anasazi (Frazier).

farming sites on the main valley floors. In the last 20 years an impressive network of roads, often 30 feet wide and running in straight lines in defiance of local topography, have been discovered that emanate from Chaco Canyon to numerous outlier sites. Two of these outliers are Kin Ya'a, approximately one mile east of the Crownpoint site, and Muddy Water, which adjoins the Unit 1 site (Frazier 1986). The Chacoan culture, much of which is protected as a national monument, has injected much intrigue and mystery into generations of visitors and archaeologists alike.

The Anasazi culture began a long period of decline between the mid-1100's and 1300. Evidence appears to indicate that long periods of drought accompanied by human-induced environmental damage brought an end to Anasazi culture. People gradually migrated out of today's Four Corners region encompassing the project sites and left it virtually devoid of inhabitants. Their destination often was to the south and west, where they most probably mixed with local populations to create the Acoma, Zuni, and Hopi peoples of today—who claim lineage to the Anasazi. The migration legends of the Zuni (Ferguson and Hart 1990) and the Hopi (Courlander 1987) relate how their member clans migrated for many years throughout the Anasazi region in their quests to find the final homes they believe their gods destined them to have.

Numerous Anasazi sites have been located at all three project sites. Although the structures and other artifacts are not as spectacular as those found at such well known protected areas as Chaco Canyon, with which they are affiliated culturally, and Mesa Verde, they are deemed worthy of preservation and scientific study (Marshall 1989, 1991, 1992; Klager 1979; Ford and Dehoff 1977) See Sections 3.9.2, 3.9.3, and 3.9.4.

Pueblo IV

Pueblo IV defines the period between the end of the Anasazi culture and the entrance into the Southwest from Mexico of the first Spanish conquistadores in 1540 led by Francisco Vasquez de Coronado. Perhaps because of deteriorating environmental conditions, warfare, or other reasons, the regional population declined by as much as half over the Pueblo IV period (LeBlanc 1989). Local populations in Acoma and Zuni left many smaller pueblos and congregated in larger ones of hundreds of rooms (Cordell and Gumerman 1989). Trade did flourish throughout an extensive region, and the Acoma and Zuni area may have served a middleman role between the Hohokom culture in southern Arizona and the pueblos along the northern Rio Grande (Le Blanc 1989).

It was during this period that the Navajo likely migrated into northwestern New Mexico. The timing of Navajo entry into the area has been estimated by various authorities to have been as early as 1000 and as late as 1525. It is reasonably certain that the Navajos, members of the Apachean tribes, who in turn were associated with the Athapaskan culture, were at least on the northern periphery of the Anasazi region around 1300. This dating would put the Navajo at least in contact with the Anasazi at the demise of their culture in the Four Corners region. However, "it is still uncertain whether they had any influence on the Puebloan abandonment of vast regions about this time" (Brugge 1983). Locke argues that it is unreasonable to presume that wandering bands of hunters and seed gatherers with a distinctly poorer culture could have been able to do much real damage to the more advanced Anasazi (Locke 1992).

The Navajo were a nomadic people who apparently migrated along the Rocky Mountains from much further north and may have been joined by smaller numbers of their kinsman from California. This migration could have begun a thousand years ago and involved a lengthy process in which small bands

were on the move, eventually settling throughout much of the Southwest (Locke 1992; Brugge 1983). Upon reaching the Four Corners region, they stopped their migration and took up a nomadic lifestyle within the region. They began borrowing various attributes of the indigenous Indians' cultures. Little is known about the Navajo during this time. Their lifestyle of moving from one location to another to secure basic resources brought them into conflict with the Puebloan cultures. Their legends tell of inhabiting abandoned Anasazi structures as the need arose (Locke 1992). Generally, Navajo and other Apachean tribes can be viewed during this period as relative newcomers endeavoring to elbow their way into whatever niches they could find or create in the human environment of the region.

To date, no artifacts from the Pueblo IV period have been identified at the three project sites. Permanent settlements may not have been established in the Crownpoint area following its general depopulation; consequently, far fewer artifacts would be expected to be found in the area.

3.9.1.2 Post-contact (1540 A.D. to Present)

Spanish Period

The Spanish conquistadores, who arrived in 1540 and returned intermittently until the end of the century, constituted the shock troops of cultural change to Native American societies in the Southwest. The only redeeming feature of their visits for the Indians was that each expedition left, often after it had spread considerable death and destruction among the Puebloan tribes who were in the way. The Spanish made their presence permanent in northern New Mexico with the 1598 expedition of Juan de Onate, who brought 400 soldiers, colonists, priests, and servants to colonize the upper Rio Grande Valley and convert the Indians to Christianity (Simmons 1979). Onate implemented harsh measures against those tribes who opposed his attempt to establish Spanish dominion over the region. Acoma Indians at Sky City, probable descendants of some Anasazi who had lived in the Crownpoint area centuries before, were killed by the hundreds. Hundreds more either were captured, hacked to pieces, and thrown off the mesa top or enslaved by the Spanish-males after having one foot cut off (Locke 1992).

In the ensuing century, the Spanish instituted their control over the region and its indigenous population. Frustrated in their search for the gold and silver of their legends, the Spanish turned to ranching, trading with the Indians, spreading the faith, and generally trying to settle the region. Relations with Indians—Puebloan, Navajo, and Apache—were troublesome and varied greatly among the tribes and over time. The Spanish introduced sheep, cattle, and horses to the Southwest, and the Indians quickly tried to capitalize on these resources even though they were prohibited from owning their own herds. During this period, the Navajo changed from a relatively backward culture who moved about periodically in search of improved agricultural, hunting, and gathering prospects to a more advanced culture based on herding of livestock for their sustenance and wealth (Locke 1992). The period was particularly unhappy for the Indians who suffered through continuous efforts by the missionaries to destroy their religions and substitute Roman Catholicism. Given the central and very broadly-defined meaning of the term religion in Indian culture, any attempts to abolish it had profound effects on the Indians. In addition, almost all pueblos suffered substantial population declines because of battles with the Spanish and the Navajo, susceptibility to European diseases, and famines (Simmons 1979).

Spanish rule was suspended for a 12-year period after the famous Pueblo Revolt of 1680 in which every Puebloan tribe rose in unison against the Spanish, killing many of the priests, who were seen as the closest

and most obvious instruments of oppression. Once Spanish control was reasserted, the situation for Indians reverted to its rather dismal pre-Revolt conditions except the authority of the Catholic Church was reduced. Many Indians were captured by the Spanish or other tribes and sold into bondage to Spanish settlers, ostensibly to Christianize them. Some Spanish were likewise captured by the Indians (Locke 1992; Simmons 1979). Miscegenation among the Indian tribes and between Indians and Spanish brought about significant change in the ethnic composition of many groups. Periodic strife with the Spanish and European diseases continued to ravage the Pueblos.

One source of some relief for Puebloans along the northern Rio Grande was to flee west to the Acoma, Zuni, Navajo, or Hopi tribes, where Spanish control was much reduced or virtually absent, as with the Hopi. In the Hopi case, the tribe welcomed a group of Tewa Indians as permanent residents in exchange for their help in fending off the Spanish and other interlopers. The Hopi also exterminated one of their own pueblos, Awatovi, in 1700 because of anger that its people had become to close to, and subverted by, the Spanish (Courlander 1987). Even today these western Pueblos, particularly the Hopi, are some of the most resistant tribes any where to outside acculturation. This point is critical today in understanding the potential for impacting Indian lands, artifacts, and traditional cultural properties. These modern day tribes are determined to preserve their culture.

In 1821, a newly-independent Mexico assumed control of the Southwest from the Spanish. Indians were granted equality of citizenship with other people, and the status of the Catholic Church continued to decline. Otherwise, the fate of the Indians continued as before (Simmons 1979). Interestingly, one tribe that improved its conditions in terms of land and livestock, as it had for sometime, was the Navajo.

No artifacts have been identified at any of the three project sites that can be assigned to the 300 years of Spanish and Mexican rule. In respect to Crownpoint and Unit 1, the Navajo apparently did not enter this area, except as transients, until about the late 1860's following the Bosque-Redondo imprisonment discussed below (Marshall 1991). The area could have been used for hunting and gathering by other tribes, but no physical evidence has been found as of yet to support such a presence.

American Period

The American period began in 1846 with the occupation of the Southwest by American military forces and the establishment of American civil government. The traditional, agrarian society of the Spanish and, briefly, Mexicans was replaced by a far more vibrant, commercial, anti-status quo American culture committed to the precepts of Manifest Destiny.

Seeking to establish control over a vast, new acquisition, American officials initially pursued an open-handed policy toward all the region's inhabitants. With continuing livestock raids, kidnaping, and depredations, the Navajos were eventually singled out by American authorities as the culprits. Several punitive expeditions were mounted against them which ultimately led to the imprisonment of as many as 10,000 Navajos at Bosque Redondo between 1864 and 1868. The ordeal subjected them to starvation, disease, emotional trauma, murder, and pillaging from virtually all their antagonists be they the army, settlers, or other Indians (Locke 1992; Roessel 1983). In one of the early groups of over 2500 Navajos, 323 died before reaching Bosque Redondo which was over 300 miles from their starting point. Some who could not keep up were shot by soldiers, others were captured by settlers and sold or kept as slaves. After much soul-searching in New Mexico and Washington, the imprisonment was ended in 1868 and the Navajo

returned to their land, now reduced to one-tenth its original size (Roessel 1983). The return of their land would become an on-going and, gradually, attainable objective of the Navajo from that time onward.

While animosities between the Navajo and the Puebloan tribes continued along traditional lines, all suffered from federal policies to "civilize" the Indians. Most of the tribes experienced cultural threats from external forces, including missionaries from numerous Christian sects, forced removal of children to distant boarding schools for "white education"; federally-imposed, wealth-threatening stock reduction programs; and centralized forms of tribal governments. Some continued to lose their land to others, including the Zuni, who lost land as late as 1939 (Ferguson and Hart 1990). It was not until the 1920s and 1930s that federal policy shifted from assimilation and neglect of tribal rights to assistance through protection of tribal lands, increased tribal self-government, and economic development. In recent decades, federal policy has shifted toward not only protection and development but reinvigoration of tribal culture.

Some Navajo artifacts from this period have been found at the project sites. These include hearths, corrals, trash piles, and hogans. It should be recalled that under the Archaeological Resources Protection Act, material less than 100 years old may not be defined as an archaeological resource. The recent vintage of these sites reflects the viewpoint that the Navajo did not maintain a significant presence in the area until after 1868.

A traditional cultural resources survey of the three project sites was conducted by a Navajo practitioner of traditional ceremonies (Becenti 1996). He conducted walking tours of the three sites and interviewed several Navajo residents of the Church Rock chapter. Cultural sites important to the Navajo traditions, including gathering places for ceremonial plants, talking rocks, and sites of ceremonies, were identified as being off the project sites by one or more miles and generally in the mountains. Family graves sites are near residences and clearly marked, and sweat lodges are no longer used. The practitioner discovered no indications of traditional cultural resources during his inspection of the three sites. His report indicates that whatever Navajo shrines may have existed are no longer known or used by the Navajo. All three sites have been heavily grazed by livestock, making them unsuitable for collecting herbs, and the presence of roads eliminates whatever sacredness that might have existed at an earlier time (Becenti 1996).

The findings of the Navajo practitioner were supported by two other knowledgeable Navajo from the Crownpoint area. They indicated that the Mount Taylor and Hosta Butte areas were far better suited as locations for traditional cultural resources (HRI 1996c).

The cultural history documented above is important in understanding the present day culture of the region in which HRI proposes to construct and operate its ISL project. The cultural history reveals the complex relationship among Native American peoples that evolved over thousands of years prior to contact with European civilization. The relative balance of power among Native American tribes was upset by the arrival of the Spanish in the mid-sixteenth century. The result was the partial displacement and partial assimilation of the indigenous cultures by the stronger, external culture imposed by force-of-arms. This situation lasted for about three centuries until a much stronger alien culture imposed itself on the region. The result is the culture of the American Southwest of today in which the dominant Anglo culture is modified in localities with sizeable Native American or Hispanic populations. Such localities typically manifest a blend of two or three cultures. Whereas past American government policy was to assimilate these cultures into the American "melting pot," policy in recent decades has been to encourage preservation of minority cultures. This policy is particularly aimed at preserving Native American cultures. Such

devices as increased tribal autonomy, an end to programs intended to assimilate Indians into the Anglo culture, protection of Native American religion, preservation of traditional cultural properties, and repatriation of grave goods and important cultural artifacts to appropriate tribes have been established to help preserve Native American cultures. This NEPA analysis, carried out primarily under the provisions of the National Historic Preservation Act (as amended), is one component of the federal government's efforts to sustain and reinvigorate Native American cultures. Since the proposed project could occur on Native American land rich in cultural artifacts, and its operation would affect the everyday lives of mostly Native Americans, the cultural resource analysis has emphasized these concerns.

3.9.2 Crownpoint

Most of the Crownpoint site has been surveyed for archaeological resources (Marshall 1989; Klager 1979; Marshall 1992). No sites were identified that are presently on the National Register of Historic Places. However, Marshall (1992) reports that:

> numerous cultural properties that qualify for nomination to the National Register are probably present in the lease area. Other sites that qualify for preservation under the American Indian Religious Freedom Act and the Navajo Nation Policy to Protect Traditional Cultural Properties are also likely to be present.

For all practical purposes, current knowledge about people living in the Crownpoint area begins with the Anasazi since no records or artifacts for the area exist before the Anasazi period. Two protected areas that are components of the Chaco Culture National Historical Park, Muddy Water and Kin Ya'a (the latter of which is on the National Register), are located as close as one mile to the northwest and east, respectively, of the Crownpoint site. The Anasazi people inhabited these communities from as early as AD 400 to 1150. This 750-year period encompasses the early Basketmaker III to early Pueblo III cultural eras. Kin Ya'a is a so-called tower kiva approximately four stories tall. It is considered by the Navajo to be the home of their *Kii ya anii* clan, one of the original four clans portrayed in the Navajo origin legend, and is associated with an important Navajo rite known as the Blessingway. Kin Ya'a is on the "Great South Road" that connected outlying Anasazi communities with Chaco Canyon; an additional Anasazi road may connect Kin Ya'a to Muddy Water.

Most of the 15 Anasazi sites that have been identified in the eastern two-thirds of the Crownpoint site are associated with the Kin Ya'a community. Based on a density of 50 to 100 sites per square mile, Marshall estimates that an additional 20 Anasazi sites are present in this portion of the Crownpoint site.

Nine additional Anasazi sites encompassing Basketmaker III through Pueblo II eras have been identified in the western third of the Crownpoint site in separate surveys conducted by Marshall (1989) and Klager (1979). These sites are believed to be associated with the Muddy Water community. Two Chacoan road segments pass through the area from the southwest.

In the potential land application area (Section 12, T17N R13W) north of Crownpoint, five Anasazi sites were identified in an archaeological survey about 20 years old. This is a surprisingly small number in view of the size of the area and its proximity to areas with far greater densities of sites. The Anasazi sites do not appear to be of great consequence from an archaeological standpoint. They date from approximately the 10th to 12th centuries A.D. and have been severely damaged by natural forces and livestock. They consist

of small campsites, hearths, perhaps the remains of one or two small structures, and potsherds (Brooks n.d.).

The Anasazi sites in the Crownpoint site appear to be typical of those found throughout the San Juan basin. They range from Basketmaker III sites comprised mostly of potsherds, hearths, and pithouses to the more elaborate, larger buildings and specialized structures associated with the Pueblo II and III eras.

The structures, which are collapsed to one or perhaps two stories and filled in with wind- and water-borne soil, are difficult for the untrained eye to identify. While some structures originally were fairly large roomblocks, none approaches the spectacular pueblos still standing in Chaco Canyon. This fact does not negate the need to preserve these sites and, perhaps, eventually excavate them to add to our knowledge of Anasazi culture. Marshall (1992) points to much that can probably be learned about how Chacoan communities evolved over their lengthy history, how agriculture was practiced in such dry climates, how trade in exotic goods occurred, and what functions were performed by the wide, straight Chacoan roads for a people without knowledge of the wheel or beasts of burden.

As the Pueblo III period progressed, Anasazi culture throughout the San Juan basin went into decline, probably because of periodic, lengthy droughts; erosion of farmland and forests; and, perhaps, raiding by, or warfare with, other tribes though the evidence for the latter is meager (see Appendix B). The Anasazi are believed to have migrated in small groups over a lengthy period to new areas. In the Crownpoint region, likely new homelands would be toward the south to the areas inhabited by the predecessors of the modern day Zuni and Acoma tribes, and possibly toward the west in the area of the Hopi tribe. These tribes claim descent from the Anasazi, and their origin legends speak of their clans migrating through the Crownpoint region in search of their final homelands. The area apparently became virtually devoid of people; and eventually, the Zuni and, perhaps, others used it as a hunting and gathering area (Ferguson and Hart 1990).

Ultimately, the Crownpoint area was again repopulated. The new residents were the semi-nomadic Navajo, who were part of the larger Athabaskan (or Apachean) group of Indians who had migrated south over a lengthy period of time. The date of the Navajo's entry to the Crownpoint area is uncertain, but the evidence from surrounding locales would indicate the early 1700s. No Navajo sites from the period have been identified in the Crownpoint site; indeed, virtually all sites discovered in the archaeological surveys have been from the last 100 years (Marshall 1992). The earliest historical records for Navajo habitation are the late 1860s after the tribe's resettlement following their four-year imprisonment at Bosque Redondo. Most settlement occurred after 1910 when the village of Crownpoint was established as the location for the BIA office for managing the eastern part of the reservation.

Navajo artifacts that have been identified in the eastern two-thirds of the Crownpoint site are located at eight sites, with more expected to be found in a thorough survey. The artifacts are mostly the remains of hogans but also include hearths and trash piles (Marshall 1992). Five Navajo sites have been identified in the western third of the Crownpoint site. They include remains of hogans, hearths, sheep pens, masonry walls, and trash piles. These sites also are considered to be from about the last century (Klager 1979; Marshall 1989). Nine 20th century Navajo ruins have been identified in the Section 12 parcel. They do not qualify as archaeological sites because of their age and they are not considered to have historical significance. One burial site will require protection, however.

A traditional cultural properties survey conducted by Navajo practitioners in the Crownpoint site did not identify any sacred Navajo sites (Becenti 1996; HRI 1996c). **[Place saver for results from other tribes.]**

3.9.3 Unit 1

Approximately half of the Unit 1 site has been surveyed by a qualified archaeologist (Marshall 1991). Unit 1 adjoins both segments of the Muddy Water Chaco Protection Site, which is a component of the Chaco Culture National Historical Park as well as a New Mexico State Register archaeological district. No National Register sites occur on Unit 1. The archaeology and history of Unit 1 are similar to the Crownpoint site, as the two sites are virtually contiguous. Artifacts identified to date go back only as far as the Anasazi. A total of 33 Anasazi sites associated with the Muddy Water community have been identified, and it is estimated that an additional 40 sites are present in the lease area. Marshall estimates that the 650 to 750 year-old community consists of 750 sites in a "halo of habitation" extending out two to three miles from its center.

The Anasazi sites discovered so far can be dated as early as Basketmaker III. Nine such sites have been identified that show continuous use into the Pueblo I era. Among the artifacts discovered are pithouses, which are the underground dwellings of the time and considered to be the ancestral structures of the kivas, the cultural/ceremonial structures of later periods. Other artifacts from he earliest period include hearths, smaller masonry room blocks, lithic (chips of worked stone) and ceramic scatter and stone slabs used for various purposes (Marshall 1991). Seven sites jointly represent the Pueblo I–II years (AD 700–1100) and include masonry roomblocks, middens (trash heaps), ceramic and lithic scatter, and a kiva. The Pueblo II period alone comprises another 10 sites, including masonry roomblocks and artifact scatter. The Pueblo II–III era is represented jointly by five sites that comprise smaller masonry structures, scattered artifacts and potsherds, and a midden. Two other sites have not been identified as to their cultural era.

In addition to these artifacts, one confirmed and one possible Anasazi road pass through the Unit 1 site. The confirmed road enters the Muddy Water community from the north and then splits in two branches. One branch angles southwest where it crosses diagonally through Section 22 of the Unit 1 site. It is very difficult to detect, and its ultimate destination is unknown. The second road is a possible one that joins Muddy Water and Kin Ya'a. Evidence points to this artifact's being a road from the historical period, but conceivably the more recent road was superimposed on the path of an Anasazi road (Marshall 1991; Marshall 1992).

The post-Anasazi history of the Unit 1 site follows that of the Crownpoint site, as discussed in Section 3.9.2. The Navajo eventually moved in permanently to fill the void left by the departed Anasazi. Although Puebloan tribes and perhaps nomadic tribes as well used the area for hunting and food gathering, there is no evidence to indicate settlement by these groups. Even though the Navajo are thought to have inhabited the Lobo Plateau region since at least 1700, their settlement in the Unit 1 area appears to post-date their imprisonment at Bosque Redondo, which ended in 1868. A total of 14 Navajo sites have been located in the Unit 1 lease area that are comprised of hogans, hearths, trash piles, corrals, and other artifacts of Navajo life in the last century (Marshall 1991).

From the partial survey of the Unit 1 site, it is obvious that the area is rich in very old artifacts and that considerable research is required. This is true even though the structures all appear to be collapsed. Marshall (1991; 1992), who assessed existing surveys, completed several of his own, and developed a

management plan for further archaeological research in the lease area, argues that, "Numerous cultural properties that qualify for nomination to the National Register are clearly present in the lease area."

A traditional cultural properties survey conducted by Navajo practitioners in the Unit 1 site did not identify any sacred Navajo sites (Becenti 1996; HRI 1996c). **[Place saver for results from other tribes.]**

3.9.4 Church Rock

The Church Rock site has been surveyed by qualified archaeologists in two separate surveys (Ford and Dehoff 1977; Hurley and Marshall 1988). No sites were identified that are on the National Register or the New Mexico State Register. No sites were identified that preceded the Basketmaker III period. Four Anasazi archaeological sites, three of which appear to comprise a single complex, have been identified south of a mesa and about one mile north of the Rio Puerco in the Church Rock site (Ford and Dehoff 1977). Whereas the far more numerous Crownpoint and Unit 1 archaeological sites are affiliated either with the Kin Ya'a or Muddy War protected areas, the Church Rock sites appear to be part of a rather extensive Anasazi complex known to have existed in the Springstead area. Ford and Dehoff (1977) date the sites to the Pueblo II–III period, whereas Hurley and Marshall (1988) believe there is sufficient Basketmaker III evidence at two of the three sites at the larger complex to argue for a 500–600 A.D. settlement period at those locations.

All four sites have moderately-sized room blocks, in some cases up to 20–30 rooms, along with detached small units and middens. Some sites have hearths and kivas, and one has a roasting pit and two 10-meter long check dams composed of stacked stones that apparently were intended to reduce the velocity of storm runoff as it spilled off the mesa (Hurley and Marshall 1988).

Although some looting of burial middens apparently has occurred and bulldozers have damaged structures at two sites, archaeologists believe the sites warrant protection. Little excavating by qualified professionals has been done at the sites. As with the Crownpoint and Unit 1 sites, the Church Rock sites are essentially collapsed structures that have been covered over with wind- and water-borne soil.

Less post-Anasazi history is known about Church Rock than the other two project sites. In all probability, the Anasazi abandoned these settlements and migrated to join communities, perhaps to the south, or to start new ones of their own. There is no evidence to suggest a different fate for the Church Rock Anasazi than for those at Crownpoint or Unit 1, which fit the generally accepted view of archaeologists (Appendix B).

It is uncertain when the Navajo migrated into the Church Rock area. As with the other two project sites, the few Navajo sites identified in or near the Church Rock site date from about the last hundred years. Yet, since Navajo were semi-nomadic, they would be expected to have left less substantial sites than the Anasazi; and little might be left from earlier dates. Locke (1992) argues for the Navajo view of an earlier presence in the Southwest, pointing to reports of Spanish explorers' encounters with people called Querechos, who may have been Navajo, as well as identification of a supposed Navajo homesite south of Gallup that has been dated through dendrochronology to about 1380 (Locke 1992). In either case only one Navajo site, a late historic 2 meter circle of unmortared sandstone rocks of unknown purpose, has been located in the Church Rock site.

A traditional cultural properties survey conducted by a Navajo practitioner in the Church Rock site did not identify any sacred Navajo sites (Becenti 1996). Important cultural resources generally were considered by local Navajos to be located in the mountains one or more miles away and unaffected by HRI's proposed project (Becenti 1996).

3.10 ENVIRONMENTAL JUSTICE

3.10.1 Back, ,and and Approach

Environmental justice is

> "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no groups of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations of the execution of federal, state, local, and tribal programs and policies." (EPA 1995)

Executive Order 12898, issued February 1994, requires that federal agencies consider environmental justice in their programs, policies, and actions.

The NRC Office of Nuclear Material Safety and Safeguards (NMSS) has developed interim guidance for addressing environmental justice in EISs (NRC 1995). NMSS guidance is to be revised as appropriate based on guidance from the Council on Environmental Quality (CEQ). CEQ issued draft guidance in April 1996, which has not yet been incorporated formally into the NMSS guidance. Therefore, the approach outlined here and in Section 4.12 is in keeping with the NMSS guidance and the general direction of the CEQ guidance.

Impacts that may have environmental justice implications are health, ecological (including water quality and water availability), social, cultural, economic, and aesthetic. NMSS guidance identifies a significant environmental justice impact as one that is high and adverse (i.e., significant, unacceptable, or above generally accepted norms) and disproportionately borne by minority or low-income populations. CEQ guidance concurs, stating that an environmental impact that is not significant within the meaning of NEPA is not rendered significant if it disproportionately and adversely affects a low-income or minority population. However, CEQ indicates that the identification of effects borne by a minority or low-income population should heighten agency attention to mitigation strategies, consideration of alternatives, and preferences expressed by the affected population.

The following sections discuss the composition of the potentially affected community, public health data, the population's subsistence consumption of natural resources, and the sensitivity of the community to the potential for impacts from the proposed project.

3.10.2 Minority and Low-Income Populations in the Area of Potential Effect

The proposed project would be located in the Navajo communities of Crownpoint and Church Rock. These communities and much of the area within 50 miles of the project sites are in "Indian country" as defined in 18 U.S.C. 1151.[2] The 50-mile area of potential effect also includes almost all of McKinley County, large parts of San Juan and Cibola counties and the Navajo, Ramah Navajo, and Zuni reservations, and a small part of Sandoval County. By nearly any definition, the entire area of impact constitutes an "environmental justice population."

General demographic characteristics of the population near the proposed project sites are found in Section 3.7. Native Americans comprise 8.9 percent of the population of New Mexico, 71.8 percent of McKinley County, and 91.5 percent of the Crownpoint census designated place. Hispanics are next largest minority group in the area, comprising 11.4 percent of the population of McKinley County.[3]

In 1990, 43.5 percent of McKinley County's population was below the poverty level, up from 36.8 percent in 1980. Median household income in McKinley County is $17,468, compared to $24,087 for New Mexico. Section 3.7.1 indicates that the Native American population makes up a disproportionate number of those in poverty: 54 percent of Native Americans in McKinley County were below the poverty level in 1990.

Table 3-31 provides demographic information about the population within 10 and 50 miles of the Church Rock and Crownpoint sites. Data for New Mexico are included as reference points. Figure 3-13 verifies that the population near the project is predominantly Native American. Figure 3-14 shows the distribution of the population within 50 miles by median income. Gallup and Crownpoint are the two areas near the project sites having median incomes ≥75% of the state's median income.

3.10.3 Health Status of the Native American Population in the Area of Potential Effect

The Indian Health Service (IHS) provides health care to and records mortality statistics of the Native American population in the U.S. The IHS is organized into several area offices, one of which serves only the Navajo and Hopi populations of New Mexico and Arizona. Therefore, some Navajo-specific information about current health exists (see Tables 3-32, 3-33, 3-34, and 3-35).

Life expectancy at birth of the Navajo is 3.2 years less than for the U.S. population as a whole (Table 3-32). There are several possible contributing factors to this lower life expectancy. First, the infant mortality rate is higher among the Navajo than the U.S. population. Second, accidents play a much larger role in Navajo mortality than for the U.S. as a whole; they account for 22.6 percent of Navajo deaths compared with only 4.1 percent of U.S. deaths (Table 3-33). A higher incidence of accident-related deaths

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[2]Indian country is defined as: (a) All land within the limits of any Indian reservation under the jurisdiction of the United States government, notwithstanding the issuance of any patent, and, including rights-of-way running through the reservation; (b) All dependent Indian communities within the borders of the United State whether within the original or subsequently acquired territory thereof, and whether within or without the limits of a State; and (c) All Indian allotments, the Indian titles to which have not been extinguished, including rights-of-way running through the same (18 U.S.C. 1151).

[3]This percentage excludes persons who reported themselves as both American Indian and Hispanic.

Table 3-31. Selected demographic characteristics of the population within 10 and 50 miles of the Crownpoint and Church Rock sites

	Percent of Native American	Percent of Hispanic	Median household income ($)
New Mexico	8.9	38.2	24,087
Crownpoint: population within 10 miles	93.5	1.1	17,008
Crownpoint: population within 50 miles	62.0	18.5	16,335
Church Rock: population within 10 miles	97.2	2.0	9,874
Church Rock: population within 50 miles	74.5	11.3	15,735

Source: LandView™ II. U.S. Environmental Protection Agency and U.S. Department of Commerce.

Table 3-32. Life expectancy and infant mortality: Navajo and U.S. comparison[a]

	Navajo (1990–1992)	U.S. (1991)
Infant mortality rate (under 1 year; per 1000 live births)	9.4	8.9
Life expectancy at birth (years)	72.3	75.5
Years of productive life lost (rate per 1,000 population under 65 years of age)	101.7	55.6

[a]Statistics for "Navajo" are for those Native Americans serviced by the Navajo Area Office of the Indian Health Service. This office serves the entire Navajo reservation, the Navajo population in Indian country, and the Hopi reservation.

Source: Indian Health Service 1995. *Regional Differences in Indian Health 1995.* Office of Planning, Evaluation, and Legislation, Division of Program Statistics.

affects life expectancy statistics for the Navajo population because accidents occur to persons of all ages, while other causes of death (e.g., heart disease) tend to affect older persons. Both causes of death affect life expectancy, but a cause of death, such as accidents, that happens to a younger population can have a larger effect on life expectancy.

Although leading cause of death figures are informative, they are not ideal for comparing Navajo health status to that of the U.S. population. This limitation exists because IHS reports causes of death as the percentage of total deaths, and the high accident-related death rate among the Navajo makes other causes of death pale by comparison. Mortality rates, on the other hand, provide a measure of deaths per population, which is a more informative measure for comparison. The mortality rates (by cause—e.g., heart disease, alcoholism) reported in Table 3-34 conform to the patterns expected for populations with and without high

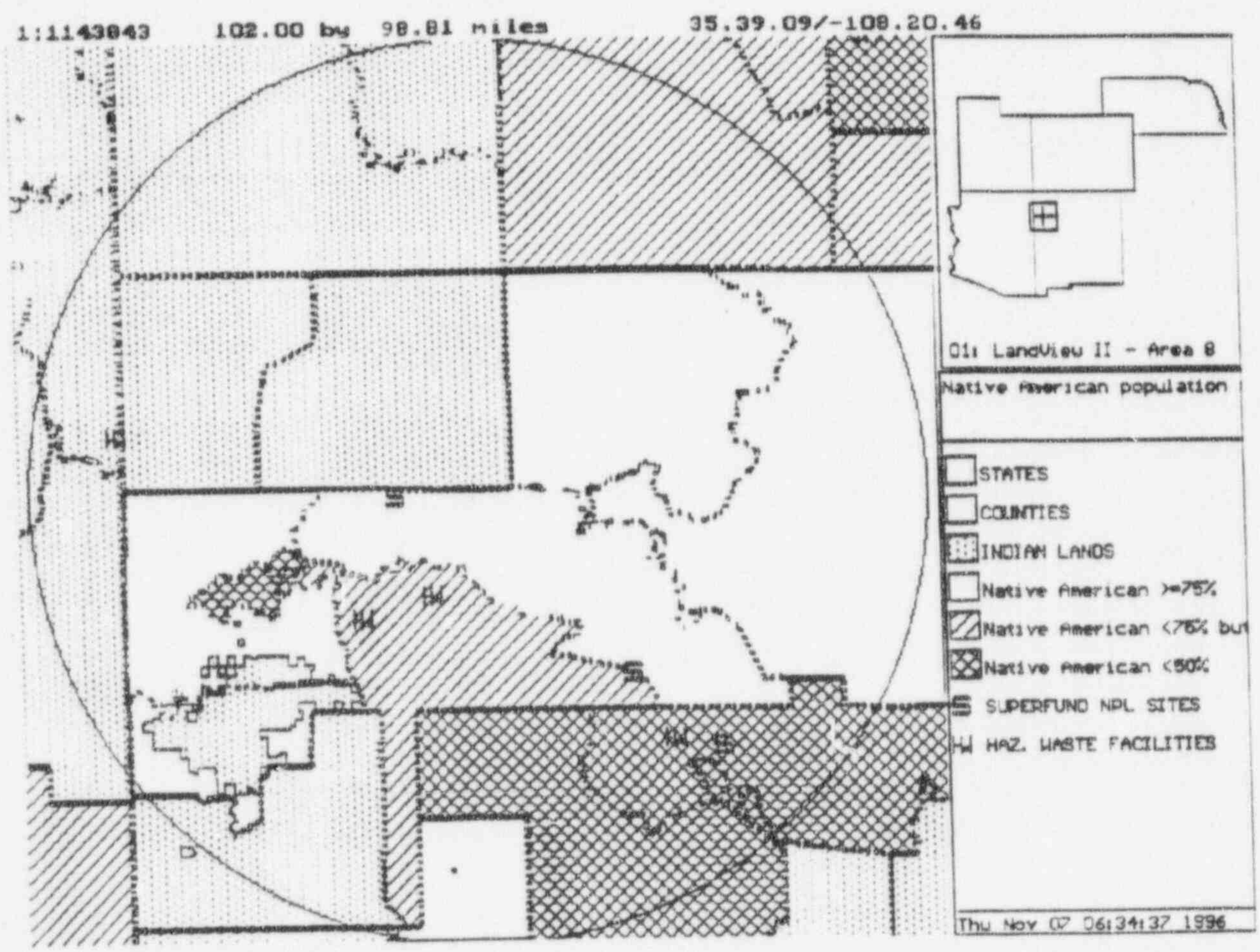

Figure 3-13. Distribution of the Native American population within 50 miles of the proposed project sites.

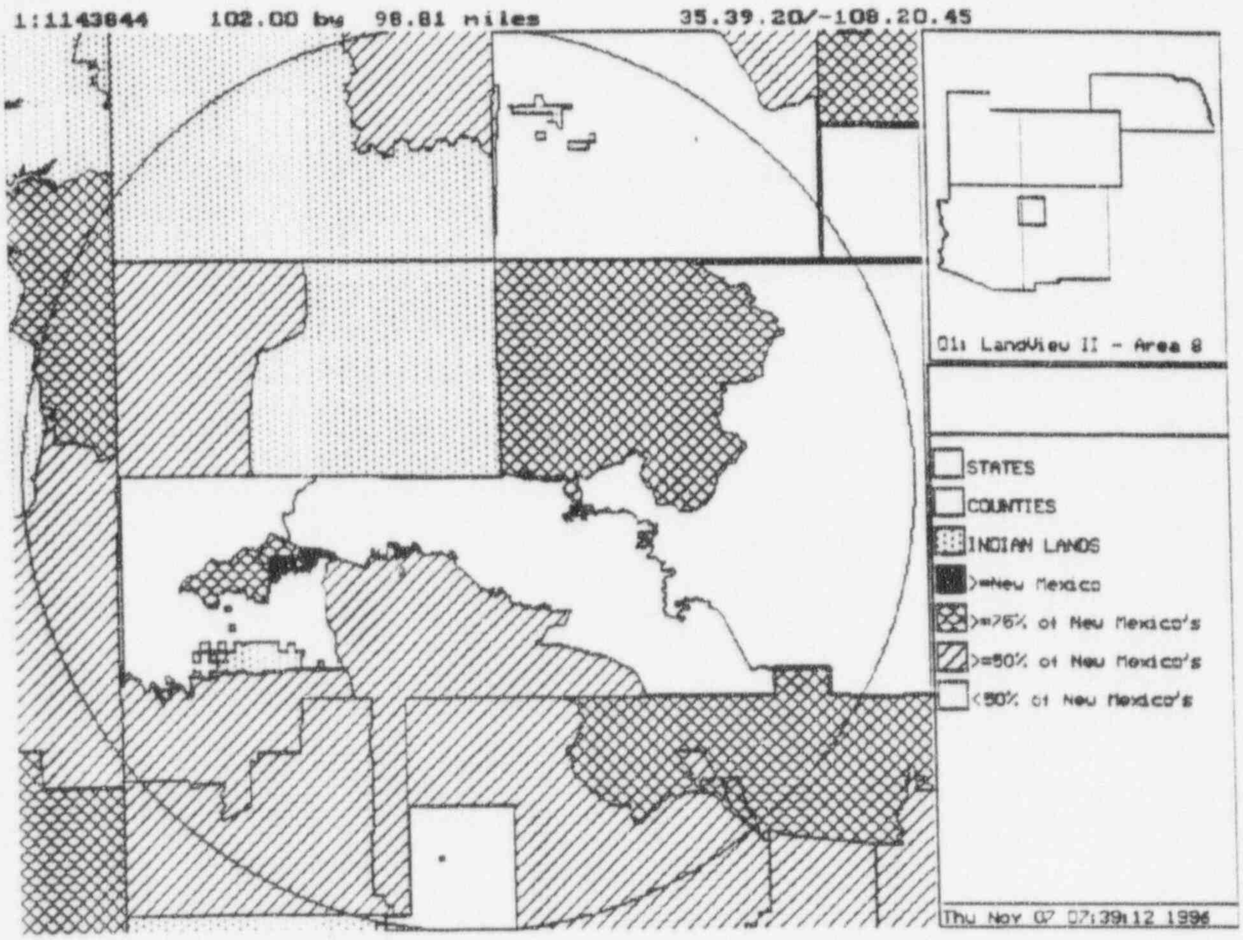

Figure 3-14. Distribution of the population within 50 miles of the proposed project sites by median income.

Table 3-33. Leading causes of death: Navajo, Native American and U.S. comparison[a,b]

Population	Causes of death (percent of total deaths)						
	Heart disease	Accidents and adverse effects	Malignant neoplasms	Diabetes mellitus	Cerebro-vascular diseases	Chronic obstructive pulmonary diseases	Pneumonia and influenza
Navajo	15.7	22.6	11.0	3.8	*	*	5.7
Native American	21.9	15.1	15.0	4.5	4.4	*	*
U.S.	33.2	4.1	23.7	*	6.6	4.2	*

*This cause of death is not among the five leading causes of death for this population. Data are reported only for the five leading causes of death.

[a]Statistics for "Navajo" are for those Native Americans service by the Navajo Area Office of the Indian Health Service. This office serves the entire Navajo reservation and Navajo population in Indian country and the Hopi reservation. "Native Americans" here means those serviced by all area offices of the Indian Health Service.

[b]Data for the Navajo and Native American populations are for 1990–1992; data for the U.S. are for 1991.

Source: Indian Health Service 1995. *Regional Differences in Indian Health 1995.* Office of Planning, Evaluation, and Legislation, Division of Program Statistics.

Table 3-34. Mortality rates by disease or cause: Navajo and U.S. comparison[a]

Cause/disease	Navajo (1990–1992)	United States (1991)
Diseases of the heart	101.7	148.2
Malignant neoplasm	78.5	134.5
Cerebrovascular	18.7	26.8
Gastrointestinal diseases	1.7	1.3
Diabetes mellitus	29.0	11.8
Tuberculosis	4.1	0.5
Accidents	143.3	31.0
Alcoholism[b]	56.8	6.8

[a]Age adjusted; rates are per 100,000 population.

[b]Alcoholism-related deaths include those occurring from diseases caused by alcoholism, e.g., alcoholic liver disease, and those resulting from alcohol overdose and psychoses.

Source: Indian Health Service 1995. *Regional Differences in Indian Health 1995.* Office of Planning, Evaluation, and Legislation, Division of Program Statistics.

Table 3-35. Leading causes of infant death; Navajo, Native American, and U.S. comparison[a]

	Causes of death (percent of total deaths)					
Population	Sudden infant death syndrome	Congenital anomalies	Disorders related to short gestation and low birth weight	Respiratory distress syndrome	Accident and adverse effects	Newborn affected by maternal completion of pregnancy
Navajo	14.7	35.0	5.5	5.5	8.6	*
Native Americans	24.3	23.7	3.5	3.8	6.3	*
U.S.	14.5	20.9	11.3	7.0	*	4.2

[a]Statistics for "Navajo" are for those Native Americans serviced by the Navajo Area Office of the Indian Health Service. This office serves the entire Navajo reservation, the Navajo population in Indian country, and the Hopi reservation. "Native Americans" here means those serviced by all area offices of the Indian Health Service.

[b]Data for the Navajo and Native American populations are from 1990–1992; data for the U.S. are for 1991.

*This cause of death is not among the five leading causes of infant mortality for this population. Data are reported only for the five leading causes of death.

Source: Indian Health Service 1995. *Regional Differences in Indian Health 1995.* Office of Planning, Evaluation, and Legislation, Division of Program Statistics.

accident-related death rates. Mortality rates resulting from heart disease, cancer, and cerebrovascular disease are lower for Navajo than for the U.S. Mortality rates resulting from alcoholism, diabetes, tuberculosis, and gastrointestinal diseases are higher among the Navajo than the U.S. population. Because of the high rate of death from alcoholism and accidents (most of which likely are related to alcohol use), Navajo may not be living as long as the rest of the U.S. population to experience diseases that are more prevalent in the elderly, such as cancer and heart disease.

Perhaps the most informative comparisons between Navajo and U.S. populations—for the purpose of identifying overall health status—are the higher infant mortality rate occurring among the Navajo[4] and those diseases that can occur at any age. In this context, tuberculosis and diabetes are appropriate foci. Both diseases are more likely to be causes of death among Navajo than among the U.S. population. Possible reasons are that these diseases are more prevalent among the Navajo or that interventions for these diseases are less likely to occur for Navajo or are less successful for Navajo than for the U.S. population.

[4]The higher infant mortality rate among the Navajo may be affected by access to health care, which also is relevant here because lack of access to health care can affect one's health. The high rate of accidental deaths among the Navajo may also be a contributing factor to infant mortality rates.

Although congenital anomalies[5] are the leading cause of infant death in the Navajo and U.S. populations alike, the percentage of deaths by congenital anomalies among Navajo infants is 15 points higher than for U.S. infants (Table 3-35). This difference is noteworthy because there is some evidence to indicate that radiation exposure may be related to the incidence of congenital anomalies (Shields et al. 1992). Researchers investigated the birth outcomes of Navajo infants born between 1964 and 1981 at the IHS hospital in Shiprock. The research concluded that there were trends in occurrences of adverse birth outcomes that lend limited support for the hypothesis that adverse genetic outcomes are related to radiation exposure. The associations were weak between unfavorable birth outcomes (including congenital anomalies and stillbirths) and radiation exposure of the parents. The only statistically significant association was identified when the mother lived near uranium mill tailings or mine dumps. However, when placing these conclusions in context, the researchers state that given the extensive uranium mining operations that have gone on for decades, including radiation exposures at levels greatly exceeding what would be allowed today, the lack of clear evidence for increased risk of adverse birth outcomes should be reassuring (Shields et al. 1992).

3.10.4 Subsistence Consumption of Natural Resources by the Native American Population in the Area of Potential Effect

Subsistence is a regular pattern of eating fish or wildlife caught or hunted for oneself or one's family, and/or eating vegetation or livestock raised for oneself or one's family. Subsistence activities are relevant in environmental justice analyses because the activities could introduce exposure pathways or pathway scenarios[6] that potentially affect a population's exposure to—and health consequences of—contamination.

Although no detailed examination of the subsistence activities of either the modern Navajo, Zuni, or Acoma population exists, some Navajo and pueblo Indians still practice traditional lifeways. Some Navajo and pueblo Indians who do not have adequate or reliable wage work to provide for themselves and their families rely heavily on their livestock and gardens (Aberle 1983). These lifeways of the Navajo include herding sheep, goats, and cattle that graze on the land and that are watered from shallow wells or the Rio Puerco. Diets of some Navajo and pueblo Indians include subsistence consumption of domestic plants (e.g., squash, corn, beans, and chiles). Both groups also harvest indigenous plants to eat and use for medicinal purposes.

3.10.5 Sensitivity of the Community to Potential Impacts of the Proposed Project

The community's sensitivity to potential adverse impacts of the proposed project is heightened by its previous experience with natural resource extraction activities, particularly uranium mining, and concern that the Navajo Nation has not been involved sufficiently in mining oversight and regulation to protect the interests of the Navajo people, particularly to safeguard their health and environment. Further, community sensitivity is heightened in the context of Navajo Nation struggles for greater self-determination and control of its resources and by the ongoing jurisdictional battle regarding "checkerboard" lands.

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[5]Congenital anomalies are those defects that occur during the infant's development in the uterus and are not acquired by heredity.

[6]Exposure pathways are the physical means through which contaminants enter the human body (e.g., ingestion, contact with skin); pathway scenarios are the activities in which people participate that might introduce an exposure pathway. An example of a pathway scenario is a child playing in contaminated dirt.

Extraction of natural resources—timber and non-renewable energy resources (coal, oil, gas, uranium)—constitutes the primary economic development on the Navajo reservation and in nearby Indian country (see Section 3.7.., Aberle 1983). These industries, located in an arid environment, use large volumes of groundwater, a situation that by itself heightens sensitivity. Although these extraction industries have employed Navajo people and provided royalties to the Nation,[7] some Navajo perceive this industrial development to have depleted Tribal resources while most of the economic benefits accrue to other people (scoping and public hearing comments; Tome 1983). This perception occurs, in part, because much of the profit from these developments accrue to private corporations outside the reservation[8] and because fixed royalty contracts were disadvantageous when prices rose. Also, there is a history, beginning with the livestock reduction of the 1930s, of compensation for negative effects being provided to others than those primarily affected by the activity. Lastly, some of these industrial developments have had adverse environmental consequences. For example, United Nuclear Corporation's uranium mill tailings dam broke in 1979. This dam break and mine dewatering activities at other uranium mines have contaminated the Rio Puerco. As a consequence, livestock that drink Rio Puerco water have high radionuclide levels (CDC 1980).

The Navajo Nation's history of not controlling or regulating resource developments on the reservation and in Indian country has influenced two pervasive beliefs among Navajo people. The first is that Navajo interests, particularly protecting the people and the environment, were not adequately addressed in the planning, implementation, and regulation of many of the industrial developments (scoping comments; Aberle 1983). Second, uranium developers are viewed as having been irresponsible (Robinson 1995). The 1979 dam break accident contributed greatly to this perception. This specific situation occurs in the context of the Navajo Nation, like other Indian tribes, struggling for greater self-determination and control of their resources and during the ongoing jurisdictional battle regarding "checkerboard" lands.

The Navajo Nation's sensitivity to uranium mining activities that could adversely affect Navajo people and its desire to exercise control over its resources is so great that the moratorium it issued on uranium mining in 1983 was renewed by tribal executive order in 1992. The moratorium on all uranium mining activity is to be effective on Navajo lands until such a time that the Navajo people are assured that the safety and health hazards associated with uranium mining activity can be addressed and resolved. There are, however, conflicts between the Navajo Nation's position and that of the chapters and individuals involved. Referenda held at the Church Rock and Crownpoint chapters, where the proposed project would be located, supported the HRI proposal despite the moratorium. Also, many allottees have agreed to lease their land to HRI. Navajo organizations have arisen to support and to object to the proposed action. The community conflict that results from this difference in opinion also contributes to a heightened sensitivity to the proposed action.

Sensitivity also is increased by concern about the health effects of uranium mining, specifically, and radiation exposure, in general. These concerns are the legacy of a period when uranium miners were

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[7]In fact, royalties paid to the Navajo Nation have been more favorable than those paid to non-Indian owners of similar resources.

[8]While it is theoretically possible for the Navajo Nation to have spearheaded the developments, lack of encouragement, expertise and risk capital prevented them from doing so.

exposed to radiation levels greatly exceeding what would be allowed today and were poorly informed of the potential health effects of radon gas (Radiation Exposure Compensation Act).

4. ENVIRONMENTAL CONSEQUENCES, MONITORING, AND MITIGATION

4.1 AIR QUALITY AND NOISE

4.1.1 Alternative 1 (the proposed action)

The potential environmental impacts of the proposed project on air quality in the local and regional area can be divided into two causal components: construction and normal operations. During construction of well fields, the gaseous and particulate releases from drilling equipment would have a minor local impact on air quality. During operations, air quality impacts would be largely limited to airborne effluents generated from processing and dust suspension due to transportation. Local increases in background noise levels would be generated by the construction vehicles, trucks, and facility operations.

4.1.1.1 Construction Activities

During well field construction, principal emissions to the air would be suspended particulates and gaseous pollutants from vehicle and drill rig exhausts, dust from vehicular traffic on unpaved roads, and dust from disturbed and unprotected soil. HRI estimates that well fields at each project site would require drilling rigs and support vehicles as summarized in Table 4-1. Estimated source terms for pollutants discharged by construction vehicles are displayed in Table 4-2.

Table 4-1. Estimated vehicle requirements for well field construction, operations, and maintenance[a]

	Church Rock	Unit 1	Crownpoint
Drilling contractors			
Drilling rigs, water trucks, support vehicles	7	6	4
Company support			
Pick-up trucks	8	8	8
Forklift	1	1	1
Portable air compressor	3	3	3
Pump hoist trucks	2	2	2
Coil tubing trucks	2	2	2
Logging trucks	1	1	1
Water trucks	2	2	2

[a]Principal vehicles during construction would be the drilling contractors, while company support would largely occur during operations.

Table 4-2. Estimated source terms for gaseous and particulate emissions from nominal 209-horsepower diesel drilling equipment[a]

Emission type	Emission rate
Sulfur oxides (SO_x)	0.93
Nitrous oxides (NO_x)	11.01
Hydrocarbons	1.41
Carbon monoxide	9.20
Particulates	1.44
Aldehydes	0.20

[a]All values are reported in grams per horsepower-hour.

Source: EPA 1991.

Non-stationary sources of air pollutants would be diesel engines on the drill rigs and diesel-powered water trucks. Drilling would proceed through the mine units with each drilling location requiring one to two days of work. Most other equipment would experience only sporadic use, and its impact on air quality would be negligible. Other mobile vehicles would be gasoline-powered onroad cars and trucks equipped with required emission control devices.

During well field construction, it is estimated that each project site would average 100 vehicle-hours per day annually (Pelizza 1996). Based on the emission rates in Table 4-2, the annual total releases and average air concentrations at each site from well field construction activities would be as shown in Table 4-3. The estimated annual average air concentration is based on the average wind speed [13 km/hr (8 mph)], land use [24 ha (60 acres)] and a mixing layer height of 1 km (0.62 mi). These estimated releases are small fractions of the allowable increments for prevention of significant deterioration of air quality (see Section 3.1.6.2).

Table 4-3. Estimated annual total releases and average air concentrations for gaseous and particulate emissions from wellfield activities

Emission type	Annual total (tonnes)	Annual average concentration (fg/m^3)
Sulfur dioxides (SO_x)	7.1	0.18
Nitrous oxides (NO_x)	84.0	2.1
Hydrocarbons	10.8	0.27
Carbon monoxide	70.2	1.8
Particulates	11.0	0.28
Aldehyde	1.5	0.04

The potential for dust emissions from wind erosion would be minimized by promptly reclaiming disturbed soil and establishing vegetative cover on soil stockpiles. Most of the work associated with well field installation would take place with stationary equipment. Therefore, dust releases resulting from vehicle traffic in the well field should be small because of low traffic volume.

4.1.1.2 Processing Emissions

Air quality impacts related to operations would be largely limited to airborne effluents generated from processing and fugitive dust generated by vehicle traffic on non-paved roads. Air pollution consisting of dust suspended by vehicle traffic associated with routine well field maintenance would be minimal. Additionally, material shipments from the Unit 1 and Church Rock sites to the central processing plant in Crownpoint would be conducted on substantially paved roads.

Air quality in the well fields and near the processing buildings would be affected by airborne effluents. Dissolved radon gas would occur in the processing solutions, and would escape into the atmosphere at several locations. First, radon would be vented in the well fields either from individual well vents or in the meter houses, or both. Also, the ion exchange (IX) system at each processing site would provide a potential escape pathway for radon. However, HRI proposes to operate the IX systems using a pressurized down-flow design. Therefore, radon releases from the plants would occur only when individual IX columns are disconnected from the pressurized recirculation system and opened to remove or elute the resins (see Section 2.1). Finally, yellowcake dryers and packaging areas could potentially release airborne particulate emissions, including natural uranium and radon daughters, to the environment.

As required, HRI modeled the radiological effects of these emissions upon the local population and surrounding area. The analysis was completed using the MILDOS-AREA computer code developed by NRC for predicting radiological doses from uranium recovery facilities. The results of these analyses are described as radiological effects in Section 4.6. In general, the estimated releases would result in very small fractions of the allowable dose limit for the general public.

Two sections of the standard transport routes between facilities would involve non-paved roads. A small section of Church Road and the access road to Unit 1 (Picnic Road) are currently non-paved, gravel roads. The additional vehicle traffic associated with the proposed project would cause adverse impacts from additional fugitive dust to residences and the churches in the immediate area of the road. HRI should investigate using dust suppression or other techniques to reduce fugitive dust emissions for the non-paved roads.

4.1.1.3 Noise

Drill rigs, construction vehicles, heavy trucks and other equipment used to construct and operate the well fields and production facilities would generate noise that would be audible above background levels of 50–60 decibels (dB) in the normal (A-scale) auditory frequency band [dB(A)] during the day. Noise resulting from the proposed project could occasionally be annoying to residents within 300 m (0.2 mile) of the noise sources. Noise levels (other than occasional instantaneous levels) resulting from the proposed project may reach or occasionally exceed 85 dB(A) at 16 m (50 ft) from the source. Because noise levels diminish by about 6 dB(A) for each doubling of distance from the source (Golden et al. 1979), nearby residents or users of multi-use facilities (e.g., churches) may experience outdoor noise levels of slightly

greater than 70 dB(A) during periods when construction equipment operates in the general vicinity. Because wellfield construction would generally occur only during daytime hours, this noise would not be expected to cause exceedances of the 24-h average sound-energy guideline of 70 dB(A) estimated by EPA (1978) to protect hearing with a margin of safety. However, outdoor noise levels at the nearest residences during the day would be expected to appreciably exceed 55 dB(A), the level given by EPA (1978) as protective against activity interference and annoyance with a margin of safety. Indoor noise levels typically range from 15 to 25 dB(A) lower than outdoor levels, depending on whether windows are open or closed. With windows open during construction hours, indoor noise levels could be substantially greater than the 45 dB(A) level given by EPA (1978) as protective against indoor interference and annoyance with a margin of safety. In summary, noise levels during well field construction and transportation of slurry and product are likely to be annoying to residences near the sources, but are not likely to be harmful.

4.1.1.4 Regional and Cumulative

The development of HRI's proposed project could limit the creation of other activities in the immediate area of its facilities. The increased fugitive dust generated on the non-paved roads could limit the use of the roads and impact the use of facilities in the immediate vicinity of the roads. Degradation of noise quality by construction activities could severely limit other activities near the well fields during construction. The potential cumulative effects of radiological effluents are discussed in Section 4.6.1.4.

4.1.2 Alternative 2 (modified action)

4.1.2.1 Alternative Sites for ISL Mining

One possible alternative to licensing the project as proposed by HRI is to limit the number of sites for ISL mining. Additional air and noise pollution in the local area could be avoided by not developing one or two of the three proposed sites. For example, developing only one of the satellite facilities would result in fewer vehicles using the non-paved section of road near the Crownpoint processing facility, reducing fugitive dust in that area. Using the Crownpoint site for yellowcake drying and packaging only (i.e., no wells at the Crownpoint site) would result in slightly smaller fugitive dust emissions than the proposed project, and would help avoid additional air and noise pollution because of the lack of well field construction.

4.1.2.2 Alternative Sites for Yellowcake Drying and Packaging

Using an alternative site for yellowcake drying and packaging would help avoid additional fugitive dust emissions around the Crownpoint facility but would not result in a complete absence of additional dust generation. If the area around the Crownpoint main facility is mined but the dryer is elsewhere, for example, in south Texas, the Crownpoint facility (now effectively a satellite facility) would need to ship slurry to the new dryer location.

Placement of the dryer in the Unit 1 or Church Rock sites would result in increased fugitive dust emissions similar to those described for the Crownpoint site in Section 4.1.1.2.

4.1.3 Alternative 3 (no action)

Under the no action alternative, air quality in the project area would remain as it is currently.

4.2 GEOLOGY AND SOILS

4.2.1 Alternative 1 (the proposed action)

During construction of the proposed project, the principal impacts on soils would result from earth moving associated with constructing waste water retention ponds and clearing drilling sites. During project operation and groundwater restoration activities, the principle impact on soils would be from on-going drilling activities and land application of project waste water. HRI has provided estimates of pond sizes and land application areas for three groundwater restoration approaches: (1) 100 percent groundwater sweep; (2) reverse osmosis treatment only; and (3) brine concentration. For the 100 percent groundwater sweep option, restoration water would be disposed of by irrigation/land application (HRI 1993b). For the reverse osmosis option, HRI would depend on deep well disposal for reverse osmosis reject water. Therefore, under this option evaporation ponds would not be constructed and land application areas will not be required. For the brine concentration option, a 8094 sq m (2 acres) pond would be constructed at each project site.

Estimates of the amounts of land that would be disturbed during well field and plant construction are provided in the following sections. These estimates also include areas for the construction of ponds for the brine concentration approach, previously identified land application areas within the site boundaries, and land that has already been disturbed by previous construction activities. Therefore, the area estimates for construction impacts are anticipated to represent worst case estimates.

4.2.1.1 Crownpoint

ISL mining activities would not result in the removal of rock matrix or structure, so unlike underground mining there should be no subsidence at the site from the collapse of overlying rock strata in the mine zone. The principal impacts on the geologic environment during project construction would result from earth moving associated with constructing waste water retention ponds and clearing drilling sites. Most of the potential impacts of construction at the Crownpoint site have already occurred because HRI purchased existing surface facilities at the site. However, the existing ponds may not be adequate and could require regrading and synthetic liners capable of retaining the waste water. Including both previously and newly disturbed areas, construction at the Crownpoint site would likely involve about 2,581,986 sq m (638 acres).

Top soil would be preserved by adopting construction practices that prevent erosion. All areas where soil is temporarily scraped away would have the soil replaced and reseeded immediately after construction (HRI 1996f).

HRI has stated that the material in the Crownpoint site ponds presently consists of windblown sand, drill cuttings, and drill mud (bentonite) (HRI 1996a). Radionuclide analysis shows that the material contains very low concentrations of uranium, radium, thorium, and lead 210. HRI plans to dispose of this material in Section 12, 17N R13W, located northwest of the Crownpoint site. HRI acquired this land from Mobil

Oil Corporation, which previously used the site for drill mud disposal. HRI plans to dispose of the existing pond material by disking (blending) it with the native soil and then reseeding the area. HRI has also identified the Section 12 property as a potential area for the off-site land application of project waste water.

Additional impacts on soils could result from spills from processing equipment. Soil contamination could result from pipeline leaks and ruptures, retention pond liner failures, or transportation accidents resulting in yellowcake or ion exchange resin spills. If soil was contaminated by a spill, the soil would be removed and disposed of in retention ponds. Ultimately, this material would be disposed of with other byproduct material at a licensed off-site disposal area. All decontamination procedures would be confirmed with radiation surveys, and would be required to meet NRC's regulations addressing radioactive materials in soils in areas released for unrestricted use.

For the Crownpoint site, all of Section 12, 17N R13W, (Figure 4-1) would be available for irrigation/land application. Section 12 is located 1 mile north of the Crownpoint site boundary and approximately 1 mile northeast of the Unit 1 site boundary. Section 12 contains 2,590,080 sq m (640 acres), but it is estimated that only 420,888 sq m (104 acres) would be needed (HRI 1996a). However, since HRI states that all of Section 12 will be available for irrigation/land application, 2,590,080 sq m (640 acres) is used in this analysis as a worst case estimate of environmental impact.

Before water is disposed of using land application, radionuclide concentrations would be reduced to acceptable levels. Metal accumulation in the soils, including selenium, molybdenum, uranium, or radium-226, is not expected to be a problem at the land application site (HRI 1996a). Soil erosion estimates, based on a conservative use of the universal soil loss equation, show that soil losses would not contribute significantly to erosion. Soils at the land application site are presently subject to wind erosion; HRI's proposed irrigation and establishment of continuous ground cover would greatly lower potential erosional losses due to wind. With irrigation applied at a rate of 0.2 inches/hr, no runoff is expected. HRI proposes to meet the following conditions (HRI 1996a):

1. No irrigation is to be carried out during a rainfall event.
2. If heavy rains are forecast, no irrigation is to be carried out in the preceding 12 hours.
3. No irrigation is to be allowed on saturated soils.
4. No irrigation is to be allowed on steep slopes or soils shallower than 72 inches.

The salinity of the proposed irrigation water would be tolerable for the irrigation of pasture grasses. However, the salinity of the irrigation water would cause permeability problems with clay soils in the irrigation plots. It is not likely that these problems would be sufficient to preclude irrigation, but monitoring of soil electrical conductivity would be required on a regular basis (HRI 1996a). In addition, if soil electrical conductivity rises to 70 percent of the maximum level tolerated by the planted crop, the irrigation area would be moved to another portion of the available land (HRI 1996a). HRI also proposes to maintain the soil sodium absorption ratio at 4 or below (HRI 1996a).

Total dissolved solids could present a problem for HRI's land application proposal. Total dissolved solids is a limiting condition for irrigation at 1,500 mg/l, and the proposed irrigation water shows total dissolved solids at 1,501 mg/l. HRI also reports that the sodium absorption ratio of the irrigation water is considered limiting at 15 (non-adjusted), while the sodium absorption ratio of the proposed irrigation water is 49.6 (adjusted). According to HRI, the existing total dissolved solid level and sodium absorption rate indicate

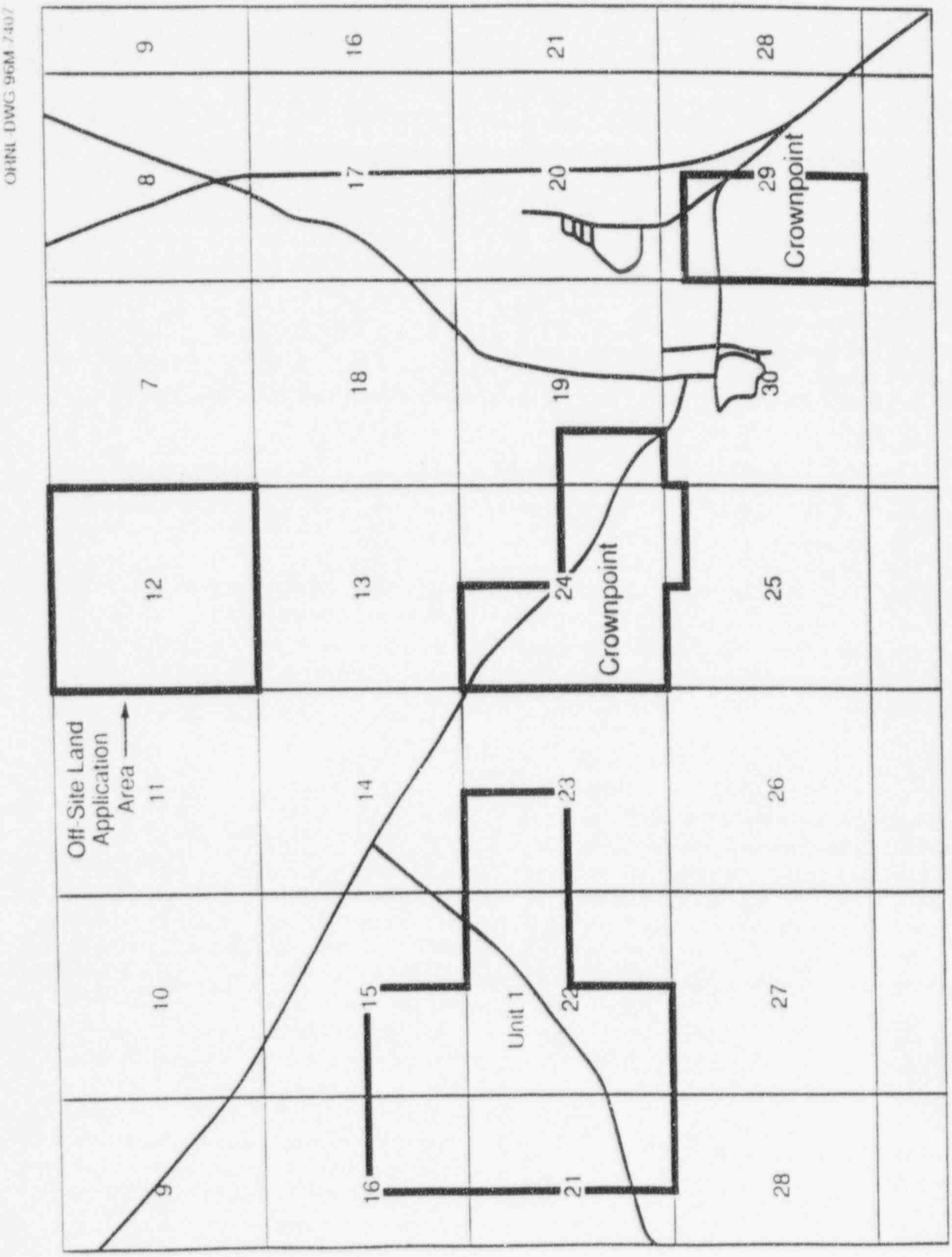

Figure 4-1. The Section 12 off-site land application area for the Crownpoint and Unit 1 sites.

that the proposed irrigation water would require close management and that soil sodium absorption ratios would require frequent monitoring (HRI 1996a). However, given HRI's proposed operating procedures it is likely that soil impacts resulting from land application would be low.

At the present time, uranium is the only economically recoverable mineral resource at the Crownpoint site. Staff believes that the proposed project would not preclude recovering other minerals that may be discovered in economic quantities at the site in the future. Assuming that only 60 percent of the uranium ore reserves are recovered by the proposed project, an estimated 8.6 million kg (19 million pounds) of uranium yellowcake would be produced from the Crownpoint site.

4.2.1.2 Unit 1

Unlike the Crownpoint site, water storage ponds would have to be constructed at the Unit 1 site to hold processing bleed and aquifer restoration water from the satellite ion exchange plant. Including both previously and newly disturbed areas, construction at the Unit 1 site would likely involve about 3,626,112 sq m (896 acres).

For the Unit 1 site, all of Section 12, T17N R13W, (Figure 4-1) would be available for irrigation/land application. This is the same location proposed for the Crownpoint site, so the impacts of land application on soil resources should be the same as those described in Section 4.2.1.1.

At the present time, uranium is the only economically recoverable mineral resource at the Unit 1 site. Staff believes that the proposed project would not preclude recovering other minerals that may be discovered in economic quantities at the site in the future. Assuming that only 60 percent of the uranium ore reserves are recovered by the proposed project, an estimated 8.6 million kg (19 million pounds) of uranium yellowcake would be produced from the Unit 1 site.

4.2.1.3 Church Rock

ISL mining activities would not result in the removal of rock matrix or structure which could cause surface subsidence. Rather, subsidence at the Church Rock site would most likely result from the collapse of preexisting mine tunnels. At present, HRI believes that most of the preexisting tunnels are intact and not collapsed. Tunnels that were open in the past during and after mining when active dewatering was ongoing are now saturated with water, decreasing the overburden pressure and increasing stability. If ISL mining were to contribute to tunnel collapse, it would likely result from the varying water pressures and vibrations associated with an operating well field. NRC staff believes that any tunnel collapse that might occur during ISL mining would eventually occur whether or not ISL mining activities were ever conducted at the site. However, if depressions appeared at the land surface due to subsurface collapse, NRC staff would require HRI to return the land surface to its original contour as part of the project's surface reclamation activities.

Most of the potential impacts of construction at the Church Rock site have already occurred because HRI purchased existing surface facilities at the site. However, the existing ponds may not be adequate and could require regrading and synthetic liners capable of retaining the waste water. Including both previously and newly disturbed areas, construction at the Church Rock site would likely involve about 1,311,741 sq m (324 acres).

Land application at the Church Rock site would probably take place on 323,760 sq m (80 acres) in Section 17, T16N R16W (HRI 1993a; HRI 1996a). HRI has conducted land application soil studies for this parcel of land in Section 17, but is also considering other properties for land application (Figure 4-2) (HRI 1996c). These properties are:

1. Flat mesa land consisting of 833,682 sq m (206 acres) on federal mining claims owned by HRI in Section 8, T16N R16W.
2. Flat mesa land consisting of 1,092,690 sq m (270 acres) on federal mining claims owned by HRI in Section 17, T16N R17W.
3. Pasture land consisting of 2,590,080 sq m (640 acres) owned by the State of New Mexico in Section 16, T16N R16W.

HRI has stated that of these three additional properties, the Section 16 parcel is the most preferable because it is the largest block of relatively flat property, it is close to the Crownpoint site, and it is at approximately the same elevation as the Crownpoint site (HRI 1996c). HRI has stated that the Section 16 parcel would be the largest parcel that would be considered for land application, and that the maximum affected area (land potentially removed from grazing) would be 2,590,080 sq m (640 acres) (HRI 1996c).

HRI proposes to file an application with NRC at the time irrigation plans for the Church Rock site have been finalized. The application would contain information about the environmental conditions of the parcel selected for land application (HRI 1996c). For purposes of evaluating potential environmental impacts in this FEIS, NRC staff have assumed that land application could occur at any of the four potential sites, but that no more than 2,590,080 sq m (640 acres) would be affected. Land application associated with the Church Rock site would have impacts similar to those described for the Crownpoint site in Section 4.2.1.1.

At the present time, uranium is the only economically recoverable mineral resource at the Church Rock site. Staff believes that the proposed project would not preclude recovering other minerals that may be discovered in economic quantities at the site in the future. Assuming that only 60 percent of the uranium ore reserves are recovered by the proposed project, an estimated 1.8 million kg (4 million pounds) of uranium yellowcake would be produced from the Church Rock site.

4.2.1.4 Regional and Cumulative

No regional impacts on geology or soil resources are expected to result from the proposed project. Cumulative soil impacts could involve the disturbance of up to 7,519,326 sq m (1,858 acres) for the project plants, well fields, and production ponds. Land application could affect an additional 5,180,160 sq m (1,280 acres). If land application is used, total worst case soil disturbance for the entire project would be 12,699,486 sq m (3,138 acres).

Assuming that only 60 percent of the uranium ore reserves are recovered by this project, an estimated 19 million kg (42 million pounds) of uranium yellowcake would be produced. Increased efficiency in HRI's uranium recovery process could drive these figures upward.

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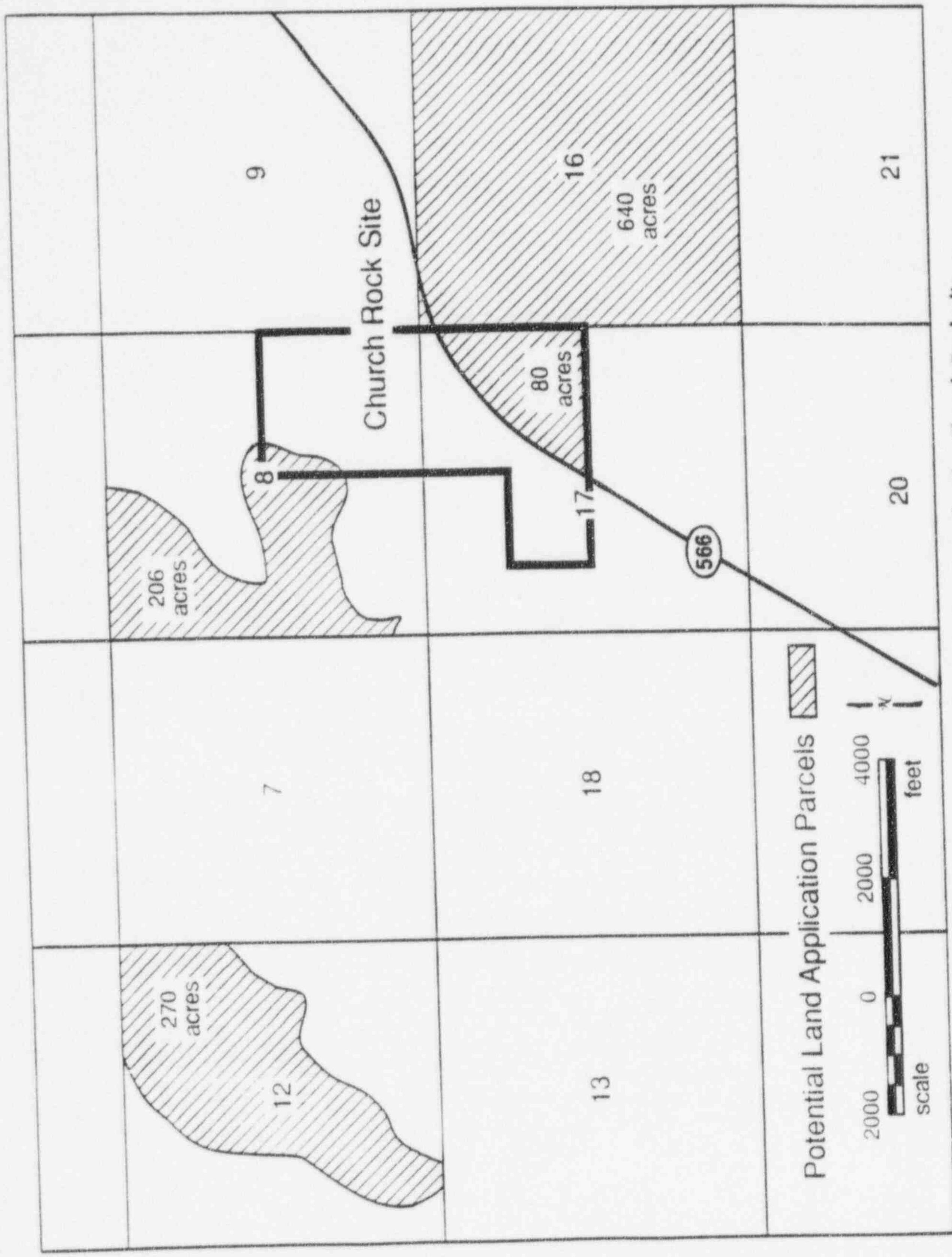

Figure 4-2. Potential land application areas for the Church Rock site.

4.2.2 Alternative 2 (modified action)

4.2.2.1 Alternative Sites for ISL Mining

The impacts of developing only one of the proposed project sites are described in Sections 4.2.1.1, 4.2.1.2, and 4.2.1.3 for the Crownpoint, Unit 1, and Church Rock sites, respectively.

Developing the Church Rock and Unit 1 sites only could involve the disturbance of up to 4,937,340 sq m (1,220 acres) for project plants, well fields, and production ponds. Land application would result in the disturbance of up to an additional 5,180,160 sq m (1,280 acres). It is projected that 10.4 million kg (23 million pounds) of uranium yellowcake would be produced by developing these two sites.

Developing the Church Rock and Crownpoint sites only could involve the disturbance of up to 3,893,727 sq m (962 acres) for project plants, well fields, and production ponds. Land application would result in the disturbance of up to an additional 5,180,160 sq m (1,280 acres). It is projected that 10.4 million kg (23 million pounds) of uranium yellowcake would be produced by developing these two sites.

Developing the Unit 1 and Crownpoint sites only could involve the disturbance of up to 6,208,098 sq m (1,534 acres) for project plants, well fields, and production ponds. Land application would result in the disturbance of up to an additional 2,590,080 sq m (640 acres). It is projected that 17.2 million kg (38 million pounds) of uranium yellowcake would be produced by developing these two sites.

4.2.2.2 Alternative Sites for Yellowcake Drying and Packaging

Impacts due to the construction of a dryer facility at either the Unit 1 or Church Rock site would be limited to a few acres. This land area would be cleared for construction of the dryer and the buildings used to store yellowcake and dried uranium.

There would be no significant impact on geologic and soil resources from using the existing drying and packaging facilities at HRI's Kingsville Dome site in Texas or at the Ambrosia Lake Uranium Mill north of Milan, New Mexico.

4.2.3 Alternative 3 (no action)

There would be no impacts to geology or soils under the no action alternative because no uranium would be produced.

4.3 GROUNDWATER

The potential groundwater impacts of ISL mining are related to the consumption of groundwater (i.e., water is pumped from the aquifer but not returned to it) and short- and long-term changes to groundwater quality (i.e., the chemistry of the water). Perhaps the most significant environmental impact that can occur as a result of ISL mining is the degradation of water quality in the ore-bearing aquifer.

During HRI's proposed project, local groundwater quality in the Westwater Canyon sandstone would deteriorate (Table 4-4). The Westwater aquifer should be the only aquifer affected by the proposed mining operations, but the local impact during mining would be adverse and significant.

Table 4-4. Average background concentrations of principal chemical species in Westwater Canyon groundwater near the Church Rock and Crownpoint sites and estimated lixiviant water quality during proposed mining operations[a]

Chemical species	Church Rock background	Crownpoint background	Lixiviant
Calcium	2.9	2.0	100–350
Magnesium	0.3	0.1	10–50
Sodium	125	110	500–1600
Potassium	2	3	0–500
Carbonate	20	27	0–500
Bicarbonate	255	195	800–1500
Sulfate	35	35	100–1200
Chloride	6	3	250–1800
Nitrate	0.02	0.04	<0.01–2
Fluoride	0.3	0.3	0.05–1
Silica	15	17	25–50
TDS	360	320	1500–5500
Uranium	0.2	0.005	50–250
Radium-226	10	0.7	>100
Conductivity	540	415	2500–7500
pH (standard units)	8.8	9.0	7.0–6.9

[a]Values are in mg/l unless specified otherwise. Data are based on HRI's groundwater sampling and operating experience (HRI 1993a).

Four phases of the ISL mining process effect the determination of impacts. The first phase involves the collection of baseline water quality and hydrologic data. This phase supplies the data which are used to assess the impacts of mining on groundwater, the success of groundwater restoration, and the success of post-restoration groundwater quality stabilization.

Prior to the commencement of mining operations, well field water quality and hydraulic data are collected. The water quality data are used to set the concentrations of parameters that will be used to determine whether the well field is being operated safely. Water quality data are also used to establish the water quality standards to which the aquifer will be restored after mining. From an environmental standpoint, the hydraulic data are used to: (1) determine whether the well field can be operated safely; (2) confirm that

monitor wells have been located correctly; (3) design aquifer restoration activities; and (4) predict post restoration impacts.

During ISL mining operations, water quality impacts are usually of greater concern than water consumption impacts because water consumption during mining is relatively small. Contamination of groundwater from sodium-based alkaline lixiviant uranium leaching arises from: (1) the addition of sodium bicarbonate and oxygen (lixiviant) to the groundwater; (2) the addition of chloride to the groundwater by the processing plant; and (3) the interaction of these chemicals with the minerals and chemical constituents of the aquifer being mined (most significantly uranium, potassium, sulfate, arsenic, selenium, molybdenum, and other trace metals) (Deutsch 1985). The result is that during mining, the concentration of most of the naturally occurring dissolved constituents will be appreciably higher than their concentrations in the original groundwater.

Water quality impacts from ISL mining are related exclusively to the identification, control, and clean-up of excursions. Excursions occur when mining solutions move beyond the "well field area" (the "well field" is the area where production and injection wells have been completed; the "well field area" is the larger area encircled by the completed monitor wells). During mining, mine solutions (groundwater altered by the injection of lixiviant) should not move horizontally beyond the well field area. For the three proposed sites, the mine zone is the Westwater Canyon aquifer. Similarly, mine solutions should not move vertically into aquifers above or below the mine zone. Wells may be placed in aquifers above and below the mine zone to monitor for vertical excursions.

An ISL monitoring program should insure that any excursion is detected long before mining solutions can seriously degrade groundwater quality outside the well field area. Early detection of excursions by a monitor well is influenced by the thickness of the aquifer monitored, the distance between the monitor wells and the well field, the distance between monitor wells, the frequency with which monitor wells are sampled, the water quality parameters that are sampled, and the concentrations of parameters that are used to determine whether an excursion has occurred.

Since it is very expensive and time-consuming to sample for every water quality parameter that could be mobilized during ISL mining, a select group of parameters (known as "upper control limit" parameters) is chosen to provide early warning that more serious contaminants are moving towards the monitor wells. An excursion is deemed to have occurred when the concentrations of the upper control limit parameters in the water sampled exceed pre-determined concentrations calculated from baseline water quality data. These pre-determined concentrations are unique for each well field.

Horizontal excursions generally occur when well field injection rates and pumping rates are not correctly balanced. If injection rates exceed pumping rates, mining solutions can move out from the well field area. However, horizontal excursions are relatively easy to detect because the mine area is surrounded by monitor wells. When a horizontal excursion is detected, the maximum width of the excursion (the distance between monitor wells) and the direction in which the excursion is traveling (horizontally from the well field) are known. In addition, horizontal excursions are relatively easy to control because the wells located in the aquifer can pump the well field at an increased rate to pull back the contaminants and correct the excursion. Thus, if a well field operator takes prompt action after a horizontal excursion has been detected, the excursion should be relatively easy to correct long before any serious water quality changes occur in the aquifer outside the well field area.

Vertical excursions occur when vertical pathways allow mining solutions to move up or down into overlying or underlying aquifers. Vertical pathways are caused by: (1) thin or missing confining units (geologic material with very low permeabilities); (2) open faults, fractures, and exploration boreholes; (3) broken casing from mining wells; and (4) injection wells operating at excessive pressures. Vertical excursions tend to occur more frequently near injection wells where the hydraulic head (water levels) exceeds the hydraulic head of any overlying or underlying aquifers. If there are no vertical pathways present, vertical excursions generally do not occur. Therefore, if a well field operator carefully characterizes, constructs, and tests the well field there is a low likelihood of occurrence.

Because vertical excursions are less likely to occur than horizontal excursions, and because of the added cost of drilling vertical wells in overlying and underlying units, vertical monitor wells are not drilled. Therefore, it generally takes longer to detect a vertical excursion than a horizontal excursion. In addition, once a vertical excursion has been detected it is more difficult to define and correct. This is because the vertical pathways must first be located and sealed. Then additional wells must be drilled into the overlying or underlying aquifer to define the extent of the excursion and correct it. Thus, if a vertical excursion occurs, water quality in the overlying or underlying aquifer is more likely to be seriously degraded and to take much longer to clean up than with a horizontal excursion.

During groundwater restoration, water consumption and water quality impacts can be significant. When restoration activities begin, water consumption increases dramatically. The amount of increase depends on the restoration techniques applied. Techniques that clean the aquifer by pumping contaminated water from the aquifer, removing the contaminants, and reinjecting the clean water into the aquifer consume the least amount of water.

Final restoration water quality standards are determined using baseline water quality data. Restoration standards are unique for each well field and usually consist of restoration on a parameter-by-parameter basis to the average baseline concentration for the well field or an appropriate state or federal water quality standard. Therefore, after successful restoration, water quality in the aquifer will not be identical to that which existed prior to mining. However, if average baseline conditions are achieved, general water quality should be close to its original condition. If water use standards are achieved, water quality should be such that water use is preserved.

Post-restoration water quality stability monitoring is solely concerned with water quality impacts. This phase of the ISL mining process occurs after well field water quality has been successfully restored. Since the geochemical conditions just after restoration are not identical to premining conditions, groundwater must be monitored for a specified period of time to ensure that aquifer water quality is not being degraded as a result of the remobilization of chemical constituents.

4.3.1 Alternative 1 (the proposed action)

The following text describes pre-mining, mining, and post-mining activities that are applicable to all three project sites. Activities that would be unique at each site are described in Sections 4.3.1.1, 4.3.1.2, and 4.3.1.3.

Premining Activities

Baseline Monitoring and Testing. Groundwater would be monitored prior to, during, and after the proposed mining operations. Prior to lixiviant injection in a well field, data would be collected to determine baseline water quality and define aquifer properties. Water quality data would be collected to establish upper control limits and restoration criteria. Prior to lixiviant injection in each mining unit:

1. Baseline water quality data would be established at (1) all mining unit perimeter monitor wells; (2) all upper and lower aquifer monitor wells; and (3) at least one production/injection well per acre in each well field.
2. Upper control limits and groundwater restoration criteria would be established (HRI 1996c).

Baseline water quality and water level data would be collected from the wells within the well field and completed in the Westwater Canyon aquifer at a density of one well per acre of well field (HRI 1996d). Baseline water quality and water level data would be collected from the first overlying aquifer at a density of one well per four acres of well field (HRI 1996c).

HRI intends to conduct additional pumping tests from production or injection wells to test the vertical confinement of a well field. HRI has identified a data gap for determining the flow direction in the Dakota Sandstone, but has committed to additional characterization or monitoring of the overlying aquifers at the three project sites before operations commence (HRI 1996c). HRI would characterize the groundwater flow direction in the overlying Dakota aquifers at the Church Rock, Unit 1, and Crownpoint properties before operations commence. HRI has committed to spacing monitor wells in the first overlying aquifer at a density of one well per four acres of field production area (HRI 1996c). There would be 11 shallow monitor wells at the Church Rock site, 24 at the Unit 1 site, and 40 at the Crownpoint site (HRI 1996c). HRI concludes that the large number of wells in the overlying aquifer would provide an adequate population of reference points to conduct contour analysis and determine flow direction, flow velocity, and water quality.

Mining Activities

Location of Monitor Wells. Monitor wells completed in the Westwater Formation (mine zone) would encircle each well field at a distance of 400 feet from the edge of the production or injection wells and 400 feet between each monitor well (HRI 1992a; HRI 1993a; HRI 1992b). Monitor wells would be located in the first overlying aquifer at a density of one well per four acres of well field (HRI 1996c). No monitoring would be conducted in the underlying Cow Springs aquifer (HRI 1996a), which is reported to be a poor producer of water. At each of the three sites the Cow Springs aquifer is separated from the Westwater Canyon aquifer by the Recapture Shale, which is estimated to be from 180 to 260 feet thick (180 feet at Church Rock and 260 feet at Unit 1 and Crownpoint). Due to the thickness of the Recapture Shale, HRI has concluded that the primary risk to any underlying water bearing sand would be deep drilling through the Recapture Shale, which, if not properly abandoned, could provide a conduit for fluid migration. With the exception of the wells near the Crownpoint site, to HRI's knowledge no holes have penetrated the entire thickness of the Recapture Shale (HRI 1996c) at any of the three project sites.

When deep monitor wells below the mining zone are used in ISL uranium mining, they are completed within the boundaries of the well field. Like production and injection wells, they are drilled through the

zone of mining. Therefore, they have to be carefully completed so that they do not become pathways that could create a vertical excursion into the underlying aquifer. HRI is concerned (HRI 1996a, Comment 63) that the primary risk to the Cow Springs aquifer would be deep drilling through the Recapture Shale, which, if not properly abandoned, could provide a conduit for fluid migration. Therefore, given the poor production rates of the Cow Springs aquifer, the lack of groundwater use from the aquifer, the thickness of the Recapture Shale, and the lack of boreholes (if any) that have penetrated it, the Cow Springs aquifer will not be monitored at any of the three sites.

Operational Monitoring. Samples from monitor wells would be collected every two weeks. Samples would be obtained with submersible pumps mounted on either a coil tubing unit which can be moved from well to well or with permanent in-place pumps in each well. An individual well would be pumped for at least 15 minutes until three consecutive samples taken at five minute intervals have consistent conductivity measurements. Thereafter, a sample would be obtained and preserved for laboratory analysis (HRI 1992d).

Upper Control Limits. Upper control limits are intended to provide early warning that mining solutions are moving away from the well fields so that groundwater outside the monitor well ring is not significantly threatened. This is accomplished by choosing parameters that are strong indicators of the ISL mining process and do not greatly attenuate due to geochemical reactions in the aquifers. If possible, the parameters chosen should be easy to analyze, allowing timely data reporting. The concentration of the chosen indicator parameters should be set high enough that false positives (false alarms due to natural fluctuations in water chemistry) are not a frequent problem, but not so high that significant groundwater quality degradation occurs by the time an excursion is identified.

Chloride is considered a strong indicator parameter for use as an upper control limit parameter because it is directly linked to the ISL mining process, it is not readily attenuated by geochemical interactions within the aquifer, and it is found at significantly higher levels in the ISL mining leachate than in natural groundwater concentrations. Calcium, sodium, and bicarbonate are also projected to be found at significantly higher levels in ISL mining leachate than in natural groundwater concentrations. The transport of calcium and sodium would be affected by ion exchange reactions between the solution and the sediment (Deutsch 1985). For that reason, bicarbonate is preferable as an excursion indicator. The use of bicarbonate inside the mineralized zone may give false alarms because of induced oxidation around a monitor well (Staub 1986). Also, Deutsch (1985) and Staub (1986) note that there is a similar concern with the use of sulfate as an excursion indicator. However, this should only be a problem if upper control limit values are set too conservatively. Of these two parameters, bicarbonate would be the preferable choice because it is mostly a direct result of the injection of the sodium bicarbonate lixiviant and should reach a high concentration early in the mining of a well field. In most natural waters, alkalinity is considered as an indication of the concentration of carbonate, bicarbonate, and hydroxide content (Greenberg 1992). The measurement of alkalinity is a common procedure and has been considered an acceptable alternative to the measurement of bicarbonate in previous NRC licenses.

Both Staub (1986) and Deutsch (1985) recommend the use of total dissolved solids as an excursion indicator, whether the mining site has relatively high total dissolved solids groundwater quality, as is often found in Texas, or relatively low total dissolved solids groundwater quality, as is found in Wyoming and at the Church Rock, Unit 1, and Crownpoint sites. Total dissolved solids has advantages as an upper control limit because it would be little effected by ion exchange reactions, it is considerably elevated in concentration by the leach solution, and is a general indicator of the chemical species elevated in the

groundwater by ISL mining. In this case, total dissolved solids would be measured as changes in specific conductivity. Conductivity is easily measured in the field and provides a good method to estimate the total dissolved solids concentration if, as is the case with ISL uranium mining, large amounts of organic matter are not present (Minear 1982; Clesceri 1990; Greenberg 1992).

In choosing the concentration for an upper control limit parameter, NRC staff guidance states that "*in order to account for the spatial and temporal variations in excursion indicator concentrations, upper control limits should be determined on a statistical basis. One such statistical technique is the student 'T' distribution*" (NRC 1981). NRC staff guidance also recommends that in some cases a simple percentage increase over baseline values may be used (a 20 percent increase over the established baseline is suggested) (NRC 1981). NRC staff has decided that it is acceptable to set baseline concentrations based on the mean plus a defined number of standard deviations. In areas of good water quality, NRC has found the mean plus 5 standard deviations to be acceptable. However, in aquifers with good water quality, chloride populations have been found to have such a tight statistical distribution that the mean plus 5 standard deviations plus a defined concentration is used.

For the proposed project, HRI would:

1. Use chloride, alkalinity, and conductivity [corrected to a temperature of 25°C, as described in Cleseri (1990)] as upper control limit parameters.
2. Set upper control limits (UCL's) concentrations for chloride, bicarbonate, and conductivity for each well field by calculating the baseline mean and adding 5 standard deviations to sampled premining mine area monitor well water quality data. Prior to calculating the baseline, mean outliers would be eliminated using a statistical method as described in the operating plan. (HRI, 1996c)

HRI has provided an example of UCL value analysis based on data collected from the Unit 1 site (Mobil Operating Area #1) without removal of outliers. Calculated UCLs were:

Conductivity	620 μmhos/l
Chloride	56 mg/l
Bicarbonate	252 mg/l

HRI has proposed using uranium as an excursion indicator (HRI 1992d). However, one of the problems with using uranium as an indicator is that while it is mobilized by ISL mining, it is not considered an early indicator that solutions are moving away from the well field and therefore is not considered a suitable parameter for an upper control limit. However, even though HRI no longer plans to monitor uranium as an excursion indicator, HRI would continue to monitor and record values for uranium during bi-weekly monitor well sampling. This is because monitoring for uranium is required by HRI's New Mexico Environmental Departmental Discharge Plan.

Excursions and Corrective Actions. Identification and confirmation of excursions at the proposed project sites would involve the following steps:

1. An excursion would be deemed to have occurred if any two excursion indicators in any monitor well exceed their respective UCLs or a single excursion indicator exceeds its UCL by 20 percent (note: it is

NRC staff's interpretation that an excursion would be deemed to have ended when only one parameter exceeds its UCL by less than 20 percent).

2. A verification sample would be taken within 24 hours after results of the first analyses are received.
3. If the second sample does not indicate that UCLs are exceeded, a third sample would be taken within 48 hours after the second set of sampling data are acquired.
4. If neither the second nor the third sample indicate that UCLs are exceeded, the first sample would be considered in error.
5. If the second or third sample contains indicators above UCLs, an excursion would be confirmed (HRI 1996a).

In the event of an excursion at any of the proposed project sites, the following corrective action programs would be applicable:

1. When excursion status is confirmed, corrective action would be required to return the water quality to the applicable UCL. During corrective action, sample frequency would be increased to weekly for the excursion indicators until the excursion is concluded.
2. An excursion is deemed to have been corrected when all control parameters have been reduced to their UCLs or below (HRI 1996a).

When an excursion has been confirmed at any of the proposed project sites, the following procedures would be applicable:

1. In the event a lixiviant excursion is confirmed by groundwater monitoring, NRC would be alerted by telephone within 24 hours and by letter within 7 days from the time the excursion is confirmed.
2. A written report describing the excursion event, corrective actions taken, and the corrective action results would be submitted to NRC within 60 days of the excursion confirmation. If wells were still on excursion when the report is submitted, the report would also contain a schedule for submittal of future reports to the NRC describing the excursion event, corrective actions taken, and results obtained. In the case of a vertical excursion, the report would also contain a projected completion date when characterization of the extent of the vertical excursion would be completed.
3. In the event that an excursion is not corrected within 60 days of confirmation, HRI would terminate injection of lixiviant within the well field until such time that aquifer cleanup is complete, or would provide an increase to the reclamation bond in an amount that is agreeable to NRC and which would cover the full cost of correcting and clean up of the excursion. The bond increase would remain in force until the excursion has been corrected. The written 60 day excursion report would state and justify which course of action would be followed (HRI 1996c; HRI 1996f).

If wells are still on excursion at the time the 60 day report is submitted to NRC and the bonding option is chosen, well field restoration bonding would be adjusted upward. To calculate the increase in bonding for horizontal excursions, it would be assumed that the entire thickness of the aquifer between the well field and the monitor wells on excursion has been contaminated with lixiviant. It would also be assumed that the width of the excursion is the distance between monitor wells on excursion plus one monitor well spacing distance on either side of the excursion. When the excursion has been corrected, the additional bonding requirements resulting from the excursion would be removed.

To calculate the increase in bonding for vertical excursions, an initial estimate of the area contaminated above background would be made. All estimates would assume that the entire thickness of the upper aquifer has been contaminated. As characterization of the extent of contamination proceeds, bonding may be increased or decreased as appropriate. Once the extent of contamination has been determined, the area which has been contaminated above background would be the area used to calculate the increased level of bonding. When the vertical excursion has been cleaned up, the additional bonding requirements resulting from the excursion would be removed.

In calculating the increase in bonding for horizontal and vertical excursions, the same formula used to calculate the number of pore volumes required to restore a well field would be applied to the assumed areas of contamination. This approach of adjustable bonding has the advantage of providing an incentive to the licensee for timely cleanup of excursions. Increased surety provides assurance that cleanup would be accomplished in the event of licensee default and can be adjusted downward once cleanup is complete. In calculating the area impacted by an excursion and the volume of water required to effect restoration, a conservative approach is taken to ensure that adequate funds are available to clean up the groundwater should the licensee fail to correct and clean up the excursion.

Well Casing Integrity Testing. If wells are not properly completed, lixiviant can flow through casing breaks and into overlying aquifers. Casing breaks can occur if the well is damaged during well construction activities. Casing breaks can also occur if water injection pressures exceed the strength of the well materials.

To inspect for casing leaks after well completion activities, each well casing would be filled with water. The well would then be pressurized up with either air or water to 862 kPa (125 psi) or 25 percent above the expected operating pressure, whichever is greater (HRI 1996a). A well would be considered to have passed the test if a pressure drop of less than 10 percent occurs over 1 hour (HRI 1992a; HRI 1992d; HRI 1992b). Operating pressure would vary with the depth of the well and would be less than formation fracture pressure.

Steel casing is much stronger than fiberglass casing, which in turn is much stronger than plastic (PVC) casing. Plastic casing would not be used at the Unit 1 or Crownpoint sites (HRI 1996a; HRI 1996c). Instead, HRI proposes to use one or more of the following casing techniques:

1. Single string of steel casing through the completion interval to be perforated.
2. Single string of fiberglass casing through the completion interval to be under reamed or perforated.
3. Dual size casing of either fiberglass or steel to accommodate large submersible pumps to pumping depth and smaller diameter casing through the completion interval (to be under reamed or perforated).
4. Dual size steel casing (as above), except that a crossover is to be made to fiberglass through the completion interval to facilitate under reaming.
5. Single string (or dual size as above) set to the top of completion interval. Below the casing, the hole would be drilled out (under reaming is optional) and screen set below the casing across the completion zone. A packer would be set inside the casing at the top of the screen. Gravel pack sand outside the screen would be optional (HRI 1996c).

Calculations by HRI and NRC staff were done to determine if the fiberglass casing could burst or collapse under well field operating pressures anticipated to occur at the Church Rock and Crownpoint sites (HRI

1996a; NRC 1996b). Using projected maximum injection pressures, NRC staff calculated the following burst safety factors for fiberglass casing at the Crownpoint and Church Rock sites:

Well head injection pressure	2,075 kPa (301 psi)
Depth to top of screen	549 m (1,800 ft)
Pressure at screen from full casing of water	5,371 kPa (779 psi) (9.8 kPa/m or 0.433 psi/ft)
Total pressure at top of screen	7,447 kPa (1,080 psi)
Burst pressure 4-inch fiberglass casing	17,238 kPa (2,500 psi)
Safety factor	131 percent
Burst pressure cement contribution	9,791 kPa (1,420 psi)
Burst pressure with cement	27,028 kPa (3,920 psi)
Safety factor with cement	262 percent

This calculated safety factor (131 percent) should represent worst case conditions because it was calculated using the deepest holes, the weakest fiberglass casing, projected maximum operating conditions, and (4) does not include the contribution by cement, which could raise the burst pressure by an additional 19,582 kPa to 23,098 kPa (2,840 psi to 3,350 psi). Using one half of the minimum cement strength of 19,582 kPa (2,840 psi) in the calculation produces a safety factor of 262 percent.

Using maximum injection pressures, NRC staff calculated collapse safety factors for fiberglass casing at the Crownpoint and Church Rock sites:

Depth to static water level	122 m (400 ft)
Depth to top of screen	549 m (1,800 ft)
Pressure outside casing from an empty casing	4,178 kPa (606 psi) (9.8 kPa/m or 0.433 psi/ft)
Collapse pressure 4-inch fiber glas[illegible]g	2,758 kPa (400 psi)
Safety [illegible]	-51.5 percent
Collapse pressure with cement	12,549kPa (1820 psi)
Safety factor with cement	200 percent

This calculated safety factor should represent worst case conditions because it was calculated for the deepest holes, used the weakest fiberglass casing, placed the pump at the greatest depth (totally dewaters the casing), and does not include the contribution of cement, which could raise the burst pressure by an additional 19,582 kPa to 23,098 kPa (2,840 psi to 3,350 psi). As a result the calculation shows that under these conditions the casing would collapse. However, using one half of the minimum cement strength of 19,582 kPa (2,840 psi) in the calculation produces a safety factor of 200 percent. Thus, there is little likelihood that fiberglass (and, therefore, steel) casing would burst or collapse under the well field operating pressures anticipated at the Church Rock, Unit 1, and Crownpoint sites.

Well Field Injection Pressures. The actual maximum injection pressures to be used in each of the mine areas would be determined when the operating wells are completed. The approximate values of allowable surface (well head) pressures for each area are 2,075 kPa (301 psi) at the Crownpoint and Unit 1 sites and 807 kPa (117 psi) at the Church Rock site (HRI 1996a). HRI proposes that at the Crownpoint and Unit 1

sites maximum operating pressure would not exceed 2,069 kPa (300 psi) (HRI 1996a). In calculating the maximum operating pressures, HRI based it's decision on projected rupture pressures for the aquifer (i.e. the creation of vertical fractures). In calculating the rupture pressure, a conservative fracture gradient of 9.3 kPa/m (0.60 psi/ft) was used, as opposed to an expected fracture gradient of 14.4 to 16 kPa/m (0.64 to 0.70 psi/ft) (HRI 1996a). NRC staff have calculated that this would result in land surface operating pressures at the Unit 1 and Crownpoint sites of from 496 to 1,234 kPa (72 psi to 179 psi) beneath expected rupture pressures, and at the Church Rock site of from 193 to 483 kPa (28 psi to 70 psi) beneath expected rupture pressures. This demonstrates that for fiberglass and steel casing, maximum injection pressures would be well below the burst/weep pressures for the casing (HRI 1996a).

Plastic (PVC) casing would only be used at the Church Rock site (HRI 1996a). Using information submitted by HRI (HRI 1996a; HRI 1993a), NRC staff calculate the following numbers for the Church Rock site (NRC 1996b):

PVC casing diameters (inches)	Burst strength kPa (psi)	Deferential pressure[a] kPa (psi)
Four	1,207 (175)	2,896 (420)
Five	1,724 (250)	2,896 (420)
Six	1,724 (250)	2,896 (420)

[a]Based on 214 m (700 ft) depth and 807 kPa (117 psi) maximum injection pressure.

This means that the maximum surface injection pressures at the Church Rock site would exceed the burst strength of the PVC casing. However, this equation does not take into account the strength of the cement sheath outside the casing. The cement would protect the casing by providing additional burst and collapse pressure resistance. HRI reports a compressive cement strength of 19,581 kPa and 23,098 kPa (2,840 psi and 3,350 psi) contributed by the cement. This additional burst and collapse pressure resistance would mean that at the Church Rock site maximum projected injection pressure would not exceed the combined cemented casing burst and collapse pressure of wells using PVC casing. However, it does mean that maximum injection pressures could easily exceed a poorly cemented PVC-cased well. However, the well testing procedure proposed by HRI (HRI 1996a) [862 kPa (125 psi) or 25 percent above the expected operating pressure, whichever is higher) should adequately test for poorly cemented wells.

Well Field Operational Flow and Pressure Monitoring. Flow rates on each injection and recovery well and injection manifold pressures on the entire system would be measured and recorded daily (HRI 1996c). During well field operations, injection pressures would not exceed the integrity test pressure at the well heads (injection pressure can be monitored for all wells with one measurement at the injection manifold) (HRI 1996c). No injection well would experience pressure significantly greater than that exhibited at the manifold.

Retention Pond Leak Detection Monitoring. HRI proposes to provide leak detection monitoring for all retention ponds. Because small amounts of condensation can accumulate in leak detection sumps, if water levels greater than 6 inches are detected, chemical assays for specific conductance and chloride would be

used to confirm the source of the water. Elevated levels of these constituents would confirm a liner leak, and would be reported to the NRC within 48 hours. Corrective actions would commence upon leak confirmation and would consist of transferring the solution to another pond so liner repairs could be made. All assay results would be reported in writing as soon as they are available.

To monitor for pond leaks, HRI would:

1. Perform and document pond freeboard and checks of the leak detection system daily, including weekends and holidays (HRI 1996a).
2. Propose the level or volume of fluid that, when exceeded in the leak detection system standpipes, would be analyzed for selected chemical constituents.
3. Propose action levels for the selected chemical constituents which, when they are exceeded, would confirm that the pond is leaking. The selected chemical constituents should be easy to analyze for and be reflective of the ISL mining process. HRI would propose at least one additive parameter and at least one mobile ionic species. Likely additive parameters which reflect ISL solutions are alkalinity or specific conductance, while appropriate ionic species would include chloride, sodium, and sulfate (HRI 1996c).

In the event that evaporation pond standpipe water analyses indicate that a pond is leaking:

1. The NRC would be notified by telephone within 48 hours of verification.
2. Standpipe water quality samples would be analyzed for leak parameters once every 7 days during the leak period and once every 7 days for at least 14 days following repairs.
3. A written report would be filed with the NRC within 30 days of first notifying the NRC that a leak exists. This report would include analytical data and describe the mitigative action and the results of that action (HRI 1996c).

HRI would maintain a log of all significant solution spills (HRI 1996c). The NRC would be notified by telephone within 48 hours of any failure which may have a radiological impact on the environment. The notification would be followed, within 7 days, by submittal of a written report detailing the conditions leading to the failure or potential failure, corrective actions taken, and results achieved. This would be done in addition to the requirements of 10 CFR Part 20.

Post-Mining Activities

Groundwater Consumption. Consumed water is the volume of water that is not returned to the aquifer. During mining, well field production bleed is estimated to be 40 gpm. However, the amount of water consumed as a result of production bleed would also vary with the aquifer restoration method used, since it would be handled just like the water produced by restoration activities. Most groundwater consumption would occur during groundwater restoration.

Groundwater Restoration. At least 90 days prior to the termination of uranium recovery in a mining unit, HRI would submit to the NRC in the form of a license amendment a plan for groundwater restoration and post-restoration monitoring (HRI 1996c). HRI proposes to use three restoration alternatives at each project site: (1) 100 percent groundwater sweep (groundwater is pumped from the aquifer, but not returned to the aquifer); (2) reverse osmosis treatment with 3 parts product and 1 part reject; and (3) brine

concentration and reverse osmosis reject with 99 parts product and 1 part reject. Under the 100 percent groundwater sweep option, waste water would be disposed of by land application or surface water discharge. Under the reverse osmosis option, wastewater would be reinjected back into the well field, into an off-site well, or both. HRI would have to acquire an injection permit from the appropriate state or federal agency before waste water could be reinjected into aquifers outside the well field and mine zone. If surface water discharge is the chosen option, appropriate state or federal permits would have to be obtained.

HRI proposes that groundwater restoration criteria be established on a parameter-by-parameter basis, and that the primary goal of restoration be to return all parameters to average pre-mining baseline conditions (HRI 1996e). In the event that water quality parameters cannot be returned to average pre-mining baseline levels through reasonable restoration efforts, the secondary goal would be to return water quality to the maximum concentration limits as specified in EPA secondary and primary drinking water regulations (40 CFR § 141 and 143.3). For barium and fluoride, the secondary restoration goal would be set to the State of New Mexico primary drinking water standard. For uranium, 300 pCi/ml (0.44 mg/l) would be used. This concentration was obtained from 10 CFR § 20 and is suitable for unrestricted release of natural uranium to water.

Under the conditions discussed above, HRI's secondary restoration goal would be equal to or below both State of New Mexico and EPA primary and secondary drinking water standards. Table 4-5 lists the parameters that would be sampled for baseline versus the primary and secondary restoration goals.

These restoration goals are consistent with the NRC Staff Technical Position Paper *Groundwater Monitoring at Uranium In Situ Solution Mines* (NRC 1981). This document states that:

"The following are recommended restoration targets.

a. Restoration results in a return to baseline groundwater quality for all indicators in all affected ground waters and in all restoration water quality monitor wells.
b. Where the baseline concentrations of a particular indicator is less than drinking water standards, the appropriate established state and federal criteria may be used to establish maximum permissible values for restoration purposes" (NRC 1981).

If groundwater restoration is successful, the proposed secondary standards would be equal to or below both federal and State of New Mexico secondary standards. These standards set concentrations for chloride, copper, iron, manganese, phenols, sulfate, total dissolved solids, zinc, and pH. Of these parameters, zinc, copper, iron, manganese, and chloride (at high concentrations) can have an effect on the taste of water (Hem 1970). It is possible that ISL mining could affect the taste and smell of groundwater. Sometimes, at the end of groundwater restoration, hydrogen sulfide is injected to reestablish reducing conditions in the aquifer. This can impart a slight rotten egg odor and a sulfur taste to the groundwater. However, this effect is not likely to last long due to the small mass of hydrogen sulfide injected relative to the large volume of groundwater and mass of rock involved.

If a groundwater parameter cannot be restored to its secondary goal, HRI would have to make a health demonstration to NRC that leaving the parameter at the higher concentration would not be a threat to public health and safety and that, on a parameter-by- parameter basis, water use would not be significantly

Table 4-5. Primary and secondary restoration goals

Parameter	Primary goal (mg/l)	Secondary goal (mg/l)
Alkalinity	Well field average	Well field average
Ammonium (as Nitrate)	Well field average	10.0
Arsenic	Well field average	0.05
Barium	Well field average	1.0
Bicarbonate	Well field average	Well field average
Boron	Well field average	Well field average
Cadmium	Well field average	0.01
Calcium	Well field average	Well field average
Carbonate	Well field average	Well field average
Chloride	Well field average	250.0
Chromium	Well field average	0.05
Copper	Well field average	1.0
Conductivity[a]	Well field average	Well field average
Fluoride	Well field average	2.0
Iron	Well field average	0.3
Lead	Well field average	0.05
Magnesium	Well field average	Well field average
Manganese	Well field average	0.05
Mercury	Well field average	0.002
Molybdenum	Well field average	Well field average
Nickel	Well field average	0.1
Nitrate	Well field average	10.0
Potassium	Well field average	Well field average
pH[b]	Well field average	6.5–8.5
Radium-226[c]	Well field average	5.0
Selenium	Well field average	0.05
Silver	Well field average	Well field average
Sodium	Well field average	Well field average
Sulfate	Well field average	250.0
TDS	Well field average	500.0
Uranium[c]	Well field average	0.44
Vanadium	Well field average	Well field average
Zinc	Well field average	5.0

[a]μmhos/cm.
[b]Unitless.
[c]pCi/L.

degraded. It is possible that this could happen with the total dissolved solids parameter at the proposed project. This parameter reflects the total sum of all dissolved constituents, but is mostly effected by the major constituents (sulfate, chloride, calcium, bicarbonate, carbonate, fluoride, sodium, and potassium). However, not all the major constituents have a secondary or primary drinking water standard (bicarbonate, carbonate, calcium, magnesium, potassium). Therefore, it is possible that after groundwater restoration the total dissolved solids secondary goal may be achieved, but may not have been achieved for those major constituents that have a secondary restoration goal of restoration to baseline. If this situation occurred, HRI would have to make a health demonstration to NRC that leaving a parameter at a higher-than-baseline concentration would not be a threat to public health and safety and that, for the parameter in question, water use would not be significantly degraded. For groundwater with total dissolved solids concentrations less than the secondary goal, staff has assumed that a worst case groundwater restoration would return water quality to the secondary goal, even though it cannot be achieved without leaving some of the major parameters at higher than background concentrations.

If groundwater restoration is successful, ISL uranium mining is not expected to affect the color of the groundwater. Dissolved organic matter is a common cause of discoloration in groundwater. A few uranium ISL mines have been known to cause discoloration in groundwater (Ford 1996a). In these instances, organic matter was dissolved in the groundwater by the oxidizing conditions created in the aquifer and/or induced microbiological activity. However, the dissolved organic matter caused fouling problems with the resin used to extract the uranium from solution. As a result, ISL uranium mining usually takes place only in aquifers with little organic matter. Conversations with HRI staff in a public meeting on June 19, 1996, and with representatives of the Wyoming mining industry (Ford 1996b) and State of Wyoming mine regulators (Ford 1996c) confirm that groundwater color is rarely changed by ISL uranium mining.

HRI believes that restoration to average baseline or State of New Mexico drinking water standards is possible in 4 pore volumes or less. Table 4-6 contains a comparison of applicable State of New Mexico and EPA drinking water standards. A pore volume is an indirect measure of the volume of water that must be pumped or processed to restore the groundwater. It represents the water that fills the void space inside a certain volume of rock or sediment. Restoration costs are often closely linked to the amount of water that must be processed to effect restoration. The pore volume parameter is used to represent how many times the contaminated volume of water in the rock must be displaced or processed to restore groundwater quality. It provides a means of comparing the level of effort required to restore groundwater regardless of the scale of the test. In general, the more pore volumes of water it takes to restore groundwater quality, the more money it will cost to effect restoration.

The success of a groundwater restoration demonstration is determined by (1) success in returning the pre-mining water quality to acceptable conditions; (2) the stability of post-restoration water quality (i.e., did the water quality stay restored?); and (3) the amount of effort required to do the restoration. With the exception of a few core scale demonstrations, HRI has relied on demonstrations that were conducted at other project locations. To demonstrate that groundwater restoration is feasible at the three proposed project sites, HRI supplied data from restoration demonstrations at other locations.

In conducting the review for this FEIS, NRC staff have had strong reservations about using a small number of small-scale core tests to demonstrate site-scale groundwater restoration. In HRI's case, 7 feet of core are being used to demonstrate the restoration potential of approximately 200 feet of aquifer over an area of about 3 square miles, with one site located about 20 miles away. However, staff also recognizes that core

Table 4-6. Comparison of State of New Mexico and U.S. Environmental Protection Agency water quality standards

Parameter	New Mexico standards (mg/l)	U.S. EPA standards (mg/l)
Parameters with primary standards		
Arsenic	0.1	0.05
Barium	1.0	2.0
Cadmium	0.01	0.01
Chromium	0.05	0.05
Fluoride	1.6	4.0
Lead	0.05	0.05
Mercury	0.002	0.002
Nickel	—	0.1
Nitrate	10.0	10.0
Radium-226[a]	30.0	5.0
Selenium	0.05	0.05
Uranium	5.0	—
Parameters with secondary standards		
Sulfate	600.0	250.0
Chloride	250.0	250.0
Copper	1.0	1.0
Iron	1.0	0.3
Manganese	0.2	0.05
TDS	1,000.0	500.0
pH[b]	6–9	6.5–8.5
Parameters with irrigation standards		
Boron	0.75	—
Molybdenum	1.0	—

[a]pCi/l.
[b]Unitless.

restoration tests can provide insight into which water quality parameters are expected to be mobilized and which parameters may be problems for restoration.

Three rock core restoration demonstrations were conducted on rock samples from the ore zone in the proposed mining areas. These were the Church Rock slow leach study, the Church Rock fast leach study, and the Crownpoint study. Tables 4-7 and 4-8 contain the results of these demonstrations. The samples were collected as cores from exploratory bore holes penetrating the Westwater Canyon sandstone. Groundwater from the ore zones was used to provide laboratory conditions as representative as possible. The water samples were fortified in the laboratory with sodium bicarbonate and hydrogen peroxide to simulate ISL mining lixiviant. Samples were prepared by crushing the rock then compacting the material into leaching columns. During the leaching phase, lixiviant was circulated through the material simulating lixiviant recirculation in a mine unit. One of the tests of the Church Rock core was run at a rapid flow rate, while the other was run slowly to more closely imitate large-scale, well field processing. Restoration was simulated by flushing the ore with baseline water, diluted 20 percent with distilled water, to simulate water treated by reverse osmosis.

Data from the Church Rock core restoration #1 (slow leach) demonstration show that uranium, radium, bicarbonate, chloride, conductivity, sulfate, and total dissolved solids could not be restored to baseline in 4 pore volumes or less. In fact, in this demonstration it took greater than 12 pore volumes to return the parameters to baseline. However, sulfate, chloride, and total dissolved solids were returned to New Mexico drinking water standards in approximately 2 pore volumes. Therefore, from the data provided it appears that all parameters except uranium and radium could eventually be returned to New Mexico drinking water standards, but not within 4 pore volumes.

In the Church Rock core restoration #2 (fast leach) demonstration, uranium, radium, bicarbonate, chloride, conductivity, and sulfate could not be restored to baseline in 4 pore volumes or less. In this demonstration, it took greater than 9 pore volumes to return the parameters to baseline. However, sulfate and chloride were returned to New Mexico drinking water standards in approximately 2 pore volumes (there are no drinking water standards for bicarbonate and conductivity). Therefore, from the data provided it appears that all the parameters except uranium and radium could be returned to New Mexico drinking water standards.

In the Crownpoint core restoration demonstration, it was observed that not all the parameters could be restored to baseline in less than 4 pore volumes. With the exception of radium, all the parameters could be returned to New Mexico drinking water standards.

A single-well pilot solution mine test was conducted in the Westwater Canyon aquifer near the Church Rock site in June 1980 by United Nuclear Corporation and Teton Exploration Company. Groundwater samples were collected before, during, and after the test to provide baseline water quality data, to monitor uranium recovery, and to demonstrate aquifer restoration. Uranium, radium, bicarbonate, calcium, selenium, boron, conductivity, nitrate, and sodium could not be restored to baseline in 4 pore volumes. However, with the exception of selenium, all the parameters were restored below New Mexico drinking water quality standards in less than 4 pore volumes. The Teton test was a larger-scale test than HRI's core restoration studies. However, the demonstration may not represent restoration of a full-scale well field because: (1) considerable dilution from uncontaminated groundwater occurs during the clean-up phase; (2) one pore volume (at most) was leached, which is much less than in a commercial operation; (3) there

Table 4-7. Results from two core leach tests conducted with ore samples from the Church Rock site

	Slow leach test			Fast leach test	
	Leach water	Pregnant lixiviant	Restored	Pregnant lixiviant	Restored
Ammonia	0.11	0.14	0.06	0.12	0.15
Bicarbonate	244	612	199	573	240
Calcium	4.9	28	3.7	14	3.9
Chloride	4	505	3.5	232	4.4
Fluoride	0.30	0.55	0.19	0.47	0.29
Iron	0.02	0.01	10.00	0.01	0.02
Nitrate	0.34	0.14	0.08	0.06	0.12
Sodium	98	515	110	341	93
Sulfate	18	8	87	4	18
TDS	289	1520	427	970	283
Arsenic	0.003	0.295	0.025	0.084	0.055
Barium	0.08	0.51	0.25	0.59	0.19
Boron	0.08	0.16	0.12	0.14	0.09
Cadmium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	<0.01	<0.01	<0.01	0.03	0.01
Copper	0.03	<0.01	0.001	<0.01	<0.01
Lead	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	<0.01	<0.01	0.10	<0.01	<0.01
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	<0.02	0.02	0.01	<0.01	<0.01
Nickel	<0.01	0.01	<0.01	<0.01	<0.01
Selenium	<0.001	0.001	0.001	<0.001	<0.001
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.03	<0.01	0.02	<0.01	<0.01
Radium (pCi/L)	1.0	1010.0	1000.0	665.0	231.0
Uranium	0.04	19.20	5.08	40.90	10.60

Source: HRI 1988; HRI 1993a.

Table 4-8. Results from the core leach test conducted with ore from the Crownpoint site

	Leach water	Pregnant lixiviant	Restored
Ammonia	<0.01	0.29	0.03
Bicarbonate	233	1543	229
Calcium	1.4	9.6	2.4
Chloride	2.8	123	2.6
Fluoride	0.40	0.45	0.29
Iron	0.50	0.01	0.01
Nitrate	0.06	0.97	<0.01
Sodium	114	739	341
Sulfate	44	71	24
TDS	339	1950	293
Arsenic	<0.001	0.077	0.003
Barium	0.04	0.18	0.06
Boron	0.07	0.08	0.05
Cadmium	<0.0001	<0.0001	<0.0001
Chromium	<0.01	0.01	<0.01
Copper	<0.01	<0.01	<0.01
Lead	<0.001	0.01	<0.001
Manganese	<0.01	<0.01	<.01
Mercury	<0.0001	<0.0001	<0.0001
Molybdenum	<0.01	0.02	<0.01
Nickel	<0.01	<0.01	<0.01
Selenium	0.001	0.078	0.010
Silver	<0.01	<0.01	<0.01
Zinc	0.02	<0.01	<0.01
Radium (pCi/L)	0.9	433.0	57.0
Uranium	0.05	7.28	0.72

Source: HRI 1992b.

was a relatively short contact time of the rock with lixiviant (5 days); and (4) fresh lixiviant was not continuously injected into the formation as would occur in an operating ISL mine.

In 1979 and 1980, another pilot project was conducted by Mobil Oil Company in conjunction with the Tennessee Valley Authority in Section 9, T17N R12W. The test, known as the Section 9 pilot project, was conducted approximately 1.5 km (1 mi) north of the Unit 1 site. Mobil used four five-spot injection well patterns to conduct the test, injecting and recirculating lixiviant for 11 months. The test only removed approximately 15 percent of the ore's uranium content. Therefore, uranium was still highly concentrated in the groundwater when restoration was begun. Additionally, the ion exchange and elution procedure apparently involved placing resin ion exchange columns while they contained elution brine. Therefore, chloride levels also became highly elevated in the groundwater (Table 4-9).

Many of the water quality parameters in the Mobil demonstration could not be returned to baseline concentrations. With the exception of molybdenum and radium, all the water quality parameters could be returned to less than State of New Mexico water quality standards. HRI states that its core results indicate that molybdenum would not be present in the Unit 1 or Crownpoint sites (HRI 1996a). The assertion that molybdenum concentrations are low in the Unit 1 and Crownpoint sites is supported by independent U.S. Geological Survey data (Leventhal 1990).

After 4 pore volumes in the Mobil demonstration, radium had been restored to about 50 pCi/L. After 16.7 pore volumes, radium had been restored to 37.4 pCi/L. This concentration does not meet the State of New Mexico drinking water standard for radium of 30 pCi/L or the EPA drinking water quality standard of 5 pCi/L. HRI anticipates that the restored value for radium at the Church Rock, Crownpoint, and Unit 1 sites would be below baseline values (HRI 1996a). This is because HRI believes that average pre-mining well field radium concentrations would exceed the State of New Mexico drinking water standard for radium (HRI 1996a). HRI cites an industry average of 159 pCi/L and believes that 231 pCi/L is in the normal range of radium values found within uranium ore bodies.

HRI's beliefs are supported by radium concentration values gathered from sampling groundwater in the Westwater Canyon aquifer at the Unit 1 and Crownpoint sites. For the Unit 1 site, a maximum radium-226 value of 200 pCi/L and an average value of 10.3 pCi/L is reported (HRI 1996b). Both of these values exceed the EPA maximum concentration limit for radium (HRI 1993b). At the Crownpoint site, a minimum radium concentration of 0.1 pCi/L and a maximum value of 806 pCi/L is reported. Using data from Crownpoint site wells CP-2, CP-3, CP-5, CP-6, CP-7, and CP-8, an average value of 65 pCi/L is calculated (HRI 1992). This exceeds the maximum concentration limit and State of New Mexico drinking water standards and reinforces HRI's projection of a baseline restoration standard for radium of 57 pCi/L (HRI 1996c). Based on industry experience, HRI believes this is typical of the level of restoration achieved with these types of uranium ore bodies (HRI 1996c).

Further analysis of Church Rock, Unit 1, and Crownpoint site water quality data indicates that a few wells are high in radium concentrations, while most of the wells are low in radium concentrations. It is this variability in radium values that explains how the town of Crownpoint wells can be located in and around a uranium deposit and still possess low radium concentrations.

HRI has provided restoration demonstration data from its production-scale ISL facilities in Texas (HRI 1996a). In the past, NRC has approved the restoration achieved using several test patterns conducted

Table 4-9. Concentration of selected chemical constituents in groundwater at the Mobil Pilot Project

	Baseline	Pregnant lixiviant	Restored	Restoration standard
Ammonia	0.47			
Bicarbonate	228	1005	225	
Calcium	5.8	320	46	
Chloride	20.3	1800	54.5	250
Fluoride	0.39	0.3	<0.5	1.6
Iron	0.67	0.02	0.146	5.5
Nitrate	0.09	0.17	0.556	10.0
Sodium	114	1600	141	
Sulfate	38	1176	47.6	600
TDS	357	5500	356	1000
Aluminum	0.02		0.808	5.0
Arsenic	0.004	0.054	0.14	0.1
Barium	0.1	0.1	0.277	1.0
Boron	0.1	0.2	0.238	0.75
Cadmium	0.006	0.01	0.006	0.036
Chromium	0.007	0.02	0.005	0.074
Cobalt	<0.05		0.021	0.05
Cyanide	0.088		<0.005	0.780
Copper	0.010	0.04	0.008	1.0
Lead	0.003	0.005	0.016	0.063
Manganese	0.050	5.85	0.035	0.456
Mercury	0.00024	0	0.0003	0.002
Molybdenum	0.172	62	1.118	1.0
Nickel	0.02	0.09	0.022	0.2
Selenium	0.01	4.6	0.006	0.05
Silver	<0.01		<0.005	0.05
Zinc	0.01	0.39	0.039	10.0
Radium (pCi/L)	<14.1	150	59.9	97.2
Uranium	0.010	145	0.319	5.0

[a]Concentrations in mg/l unless noted. Data from Mobil Oil Company (1980), Mobil Mining and Minerals Company (1986), and Mobil Alternative Energy Inc. (1986).

to explore the feasibility of ISL mining or to demonstrate that production-scale restoration of groundwater is feasible. However, at this time NRC has yet to approve restoration of a production-scale well field. The State of Texas has approved groundwater restoration of production-scale ISL facilities. However, NRC staff have observed that the Texas restoration demonstrations were in groundwater of lower quality than that of the proposed New Mexico sites. This means that the Texas sites did not have to be restored to the same level of water use as would be the case at the Westwater Canyon aquifer for the Church Rock, Crownpoint, and Unit 1 sites.

HRI proposes to complete a concurrent restoration demonstration at each of the three proposed project sites within 18 months of the date on which mining commences (HRI 1996c). The demonstration would include:

1. An isolated restoration demonstration pattern, completed in a mine unit, constructed to the same basic configuration as the proposed production well field pattern, and operated under the same conditions as the proposed mining procedures.
2. Leaching of the pattern would be run for at least 3 months under commercial activity conditions using leaching agency concentrations equal to or greater than is expected to be required for production.
3. After the leaching phase, a complete chemical description of the produced fluid would be obtained and a demonstration of a restoration would be initiated.
4. Sample analysis of fluids would be completed at least every week during the restoration demonstration to allow observation of the concentration of various restoration parameters. Progress reports would be submitted to NRC every 6 months after the demonstration is initiated.
5. Restoration would continue until the groundwater is restored to levels consistent with baseline.
6. With each progress report, the operator would calculate and submit the volume of groundwater affected. Factors to be considered include aerial extent, formation thickness, and porosity. Upon the completion of the restoration demonstration, HRI would submit the data, analysis, and conclusions in a final report.
7. Authorization for expansion of mining into additional mine units would be contingent upon the results of the restoration demonstration within the 18 month period (HRI 1996c).

The restoration tests conducted to date have demonstrated that some parameters can be restored to average pre-mining well field concentrations and that all the parameters can be restored to water use standards. However, the data do not strongly indicate that restoration to average baseline or water use standards is likely to be achieved for all groundwater quality parameters within 4 pore volumes. Therefore, NRC staff recommend that surety (bonding) for groundwater restoration of the initial well fields be based on greater than 4 pore-volume estimates. Furthermore, surety should be maintained at this level until it has been demonstrated that production-scale restoration can be achieved in 4 pore-volumes or less.

4.3.1.1 Crownpoint

Groundwater Impacts of Land Application. Groundwater contamination is not expected to occur in the Section 12 land application area because radionuclide concentrations (radium, uranium, and thorium) in the restoration water would be reduced to levels that could be released to surface water bodies and because the water table (groundwater) is at least 300 feet below the surface. Groundwater impacts from the Crownpoint facility alone would be less than the combined effect of disposing of restoration water from both the Crownpoint and Unit 1 sites.

Groundwater Impacts of ISL Mining. For the purpose of this environmental impact assessment, NRC staff assume that the flow direction in the Dakota Sandstone beneath the Unit 1 and Crownpoint sites is toward the town of Crownpoint. This assumption is based on the conservative view that the greatest potential for impact from the proposed project would be at the location of greatest groundwater use and human population.

The location of the Crownpoint site relative to the town water supply wells means that if an excursion plume occurs and is dominated by the regional flow, advective forces would act to converge groundwater flow towards the water supply wells. Groundwater flow modeling conducted by HRI to simulate a hypothetical well field at its closest point to the NTUA-1 well shows that the regional flow regime is at or beyond the outer monitor well ring (Reed 1993).

For the Crownpoint site, NRC staff have concluded that the influence of active pumping from the town water supply wells may make it more difficult to prevent excursions than at other sites that do not have to correct for the pumping influences of local wells. However, HRI's proposed well spacing is such that it is unlikely that a contaminant plume from a horizontal excursion would go undetected over the period of time that mining occurs in a well field. Therefore, if an excursion occurred there should be adequate time for corrective action.

To prevent horizontal excursions during mining and after aquifer restoration, HRI proposes to maintain a continuous bleed (pumping) at the Crownpoint site until the well fields have been declared fully restored to the required permit/regulatory limits (HRI 1996a). This would prevent the movement of water from the well fields. HRI proposes to continue the bleed in restored well fields at the Crownpoint site after restoration is verified through a stability monitoring period and until HRI receives written approval from the NRC to discontinue the bleed (HRI 1996c). Further, HRI proposes to maintain emergency generator capacity capable of maintaining a 50 gpm bleed from the mine zone throughout the mining and restoration life of the mine (HRI 1996c).

HRI conducted a groundwater flow modeling exercise for the Crownpoint site to demonstrate that solution mining could be conducted under the influence of the town of Crownpoint wells without the threat of horizontal excursions. In the model (Reed 1993), HRI simulated well field operations during summer pumping by the town of Crownpoint (as opposed to less pumping during the winter months). The modeled groundwater flow paths were contained within the well field areas. This model assumed a constant flow field. However, Crownpoint site well CP-8 is located one mile from the nearest Crownpoint water supply well (NTUA-1) and from data provided by HRI (HRI 1996a) it is observed that water levels in well CP-8 could change by 20 feet or more during a year. In addition, information provided by HRI (HRI 1992; HRI 1996a) shows water level changes on the order of five feet occurring over a period of five to six days. Therefore, it appears that groundwater gradients could be altered over the Crownpoint property in short periods of time by town groundwater withdrawals.

With sufficient balanced over-pumping of groundwater, well field solutions should be kept in the well field. The local groundwater flow direction and velocity are continuously changing due to events that cannot be controlled by HRI (i.e, individual wells being turned off and on). Therefore, mining operations would have to maintain confinement under changing hydrologic conditions. As a result, the risk of horizontal excursions is increased over hydrologic conditions commonly encountered by ISL uranium mining operations.

Vertical excursions are less likely than horizontal excursions at the Crownpoint site. Water level data indicate that the Dakota Sandstone is confined from the Westwater Canyon in Section 24 at the Crownpoint site. The difference in water levels between the Westwater Canyon and the Dakota Sandstone ranges from 80 to 100 ft (HRI 1996a). In addition, there is not a corresponding reaction in Dakota Sandstone water levels to water level changes in the Westwater Canyon that would suggest leakage. These observations are supported by a plot of Westwater Canyon (well CP-8) and Dakota Sandstone (well CP-10) water level data collected from January 1992 through March 1996 (HRI 1996a). Data collected on October 4, 1979, in Section 28, T17N R12W (one mile east of the town of Crownpoint) showed a difference of 140 feet in water levels between the Dakota Sandstone and the Westwater Canyon.

HRI has exploration drill hole survey locations for every exploration hole at the Crownpoint site (HRI 1996a). Drilling at the site began in the late 1960's and early 1970's. Therefore, all plugging at the site was in compliance with the New Mexico State Engineers Regulation NMSA Section 69-3-6, which was promulgated in 1968. HRI has all the plugging records available for the Crownpoint site (HRI 1996a). Having the surveyed locations of old exploration boreholes means that the holes would be easy to locate if they need to be plugged for suspected leaks. Having the completion records for these holes increases the confidence that the holes were sealed correctly and should not leak during ISL mining activities.

Mine shafts have been excavated from the surface into the Westwater Canyon aquifer at the Crownpoint site. The mine shafts are lined with steel and grouted to the surface. In addition, they were never cut into the Westwater unit. Therefore, they do not present an avenue for interformation transfer of groundwater.

Given the projected thickness and rock type of the overlying confining units, there should be little likelihood that faults in the Crownpoint area would act as vertical pathways for groundwater migration from the mining zone to an overlying aquifer. No significant displacement in the Westwater sands within the mining boundary (HRI 1996a) was identified by HRI after a detailed geologic evaluation of the Crownpoint site. HRI reports that there is no indication that a reported fault in Section 19 intersects the Westwater Canyon sands within the area to be mined. Available data indicate that none of the faults mapped in the vicinity of the Crownpoint site have a displacement that would significantly reduce the sand thickness and hydraulic continuity of the Westwater sands (HRI 1996a). The overlying confining unit consists of weakly indurated clay and shale, so that there is little potential for faults to act as vertical pathways (i.e., the faults are less likely to be open) for groundwater migration to an overlying sand.

However, the potential for faults to act as vertical pathways is not non-existent. This is because stratigraphic observations cannot detect a fault if it has minor stratigraphic displacement or determine if the fault is open to groundwater flow. Therefore, HRI would conduct pre-mining tests to confirm aquifer confinement.

HRI has stated that after a mine area has been identified, monitor wells (both overlying and in the production zone) and baseline mining wells would be installed (HRI 1996c). A hydrologic test would then be designed and conducted by pumping a single well relatively central to the proposed mining area. This well would be pumped at a constant flow rate so that the pressure draw down (cone-of-depression) caused by water production would stress the formation and any potential hydraulic boundaries or barriers, such as the overlying confining clays and possible non-sealing faults.

If the proposed mine area is sufficiently small, then the stress induced by pumping from a single well would test potential barriers. However, if it is determined that the observed maximum water level draw downs across the proposed mine area are inadequate to test for confinement, a second pump test would be conducted (HRI 1996c). This test would involve producing multiple wells concurrently across the area, and observing the composite effect of the resulting pressure draw down on the various monitor wells.

Plots of the water levels versus time of pumping would be made for the overlying monitor wells and evaluated for pressure responses to pumping from the mine zone. Maximum draw downs would be tabulated for each of the production zone monitor wells to ensure that adequate response was achieved for those wells (HRI 1996c). A Mine Unit Hydrologic Test Document would be assembled and submitted to the New Mexico Environmental Department for review. In accordance with NRC requirements, the Mine Unit Hydrologic Test Document would be reviewed by an HRI Safety and Environmental Review Panel to ensure that the results of the hydrologic testing and the planned mining activities are consistent with technical requirements and do not conflict with any requirement stated in the NRC license (HRI 1996c). After appropriate review of the Mine Unit Hydrologic Test Document and subsequent authorization by the New Mexico Environmental Department and HRI's Safety and Environmental Review Panel, injection of lixiviant would begin in the new mining unit (there would be no field recirculation prior to adding oxygen). Water levels would be taken on all monitor wells prior to each routine, bi-weekly water sampling and reviewed for unusual water level changes denoting any hydraulic connection with the mining zone.

In the event of a vertical excursion, HRI proposes to proceed immediately to determine the cause of the leakage and reverse the trend (HRI 1996a). Additionally, HRI would immediately drill a guard well up gradient (or as the crow flies to the closest NTUA-1 or BIA-1), 100 feet from the excursion well (HRI 1996a). If the upper control limits are exceeded in the guard well, the procedure would be repeated until unaffected water is encountered. HRI further states that a guard well would be used to monitor corrective action and to assure that an excursion cannot migrate to the public water supply (HRI 1996a).

Drilling a guard well 100 feet down-gradient from the excursion well is a good initial step in excursion definition. However, guard wells cannot be correctly located to assure an excursion would not migrate to the public water supply before the time-consuming process of identifying the extent and location of the excursion is finished. Therefore, should a vertical excursion occur identifying and correcting the excursion is likely to be a much longer process than the identification and correction of horizontal excursions.

Given the Crownpoint site geology, the previous borehole sealing procedures, and HRI's planned well integrity testing program, the risk of a vertical excursion should be low. However, staff also observe that because upper monitor wells do not encircle the well field area, but are commonly located in the center of well fields, they may not detect an excursion if a strong groundwater gradient is present. Should an excursion occur down groundwater gradient of the Dakota Sandstone aquifer monitor wells, the excursion may move undetected towards the town water supply wells. At the Crownpoint site this is important, because three of the town of Crownpoint's water wells (BIA-5, BIA-3, and BIA-6) are completed in the Dakota Sandstone as well as the Westwater Canyon Member. Pumping from the town wells could cause groundwater in the Dakota Sandstone underneath the Crownpoint site to flow towards the town water supply wells. In addition, well BIA-5 is also completed in the Cow Springs aquifer. This means that should a vertical excursion take place in the Dakota Sandstone or the Cow Springs aquifer, contamination could move towards the Crownpoint water supply wells.

Given the location and completion of the town wells, should a vertical excursion occur, there would be a need to speedily identify and correct the excursion. Furthermore, should a vertical excursion occur there would eventually be a need for a strong groundwater restoration effort in the upper or lower aquifer, because the water which has been contaminated by the excursion would eventually reach the town water supply. Therefore, to mitigate the potential impacts of a vertical excursion, staff recommends that HRI replace the town of Crownpoint water supply wells before mining is allowed at the Crownpoint site. Further, the wells should be abandoned and sealed so that they cannot become future pathways for the vertical movement of contaminants.

Groundwater Monitoring. At the Crownpoint site, the Brushy Basin member does not contain any aquifers and consists entirely of shale (HRI 1996a). Above the Dakota Sandstone is 600–700 feet of Mancos Shale. Thereafter, to the surface a number of sands form the Mesa Verde Group, the lowermost being the Gallup Sandstone. HRI proposes to monitor only the Dakota Sandstone with monitor wells spaced at a density of one per four acres (HRI 1996c). HRI does not propose to place monitor wells at the Crownpoint site in saturated sands of the Mesa Verde Group because:

1. These sands are separated from the production zone by the Dakota, which would be monitored.
2. The massive Mancos shale which separates the Dakota from the Mesa Verde group makes interformational transfer impossible.
3. Mechanical integrity well testing would assure that well casing does not leak into shallow sands of the Mesa Verde group.
4. The saturated sands of the Mesa Verde group are not substantial aquifers.

However, while HRI does not propose to place monitor wells in the deepest saturated sands of the Mesa Verde Group, if a vertical excursion is confirmed in the Dakota Sandstone at the Unit 1 or Crownpoint sites HRI would construct one or more exploration wells into the Mesa Verde (Gallup Sandstone) at the location where the excursion was identified (HRI 1996c).

NRC staff agree with HRI's determination that routine monitoring is warranted in the Dakota Sandstone, but that routine monitoring of the shallower Mesa Verde Group is not necessary. NRC staff find this approach acceptable because of the hydrologic separation between these two aquifers, and the thick, laterally extensive Mancos shale separating the two systems and because the aquifers above the Dakota Sandstone at the Crownpoint site are a not large producers of groundwater. The potential likelihood of a vertical excursion into the overlying aquifers is primarily through inadvertent leakage from installed wells. Mechanical integrity tests of injection and pumping wells provide an additional measure of safety to prevent vertical migration of injected fluids. However, should a vertical excursion occur the NRC would require that any significant aquifer above the Dakota sandstone aquifer be explored for vertical excursions as opposed to just the deepest saturated sand of the Mesa Verde Group.

As previously described, no monitoring would be conducted in the underlying Cow Springs aquifer (HRI 1996a). The Cow Springs aquifer is separated from the Westwater Canyon aquifer at each of the three sites by the Recapture Shale, which is estimated to be from 260 feet at the Crownpoint site. Due to the thickness of the Recapture Shale, HRI concludes that the primary risk to any underlying water bearing sand would be deep drilling through the Recapture Shale, which, if not properly abandoned, could provide a conduit for fluid migration. However, town of Crownpoint well BIA-5 is completed into the Dakota Sandstone aquifer, the Westwater Canyon aquifer, and the Cow Springs aquifer (HRI 1992b. In addition, a local well (Mobil

Monument Windmill) located 0.5 mile east of the Crownpoint site in Section 28 (T17N R12W) appears to be completed into the Cow Springs aquifer (HRI 1992b.

Groundwater Restoration. HRI proposes that worst case groundwater restoration targets be the higher of average premining groundwater quality background data or maximum permissible values. HRI proposes that maximum permissible values be the lower of either State of New Mexico (NMWQCC 3-103.A and 3-103b) or EPA (40 CFR § 141 and 143.3) primary and secondary standards. For uranium, 300 pCi/ml (0.44 mg/l) would be used. This concentration was obtained from Appendix B of 10 CFR § 20, and is suitable for unrestricted release of natural uranium to water.

Pumping by the town of Crownpoint controls the direction of groundwater flow in the Westwater Canyon aquifer underneath both the Crownpoint and Unit 1 sites. This means that groundwater in the Westwater Canyon aquifer beneath both properties is moving towards the town of Crownpoint wells where it would be pumped into the town water supply system. Therefore, if ISL uranium mining takes place at either the Unit 1 or Crownpoint site and the town continues to pump from its existing water supply wells as it has in the past, water which has gone through the ISL mining and restoration process would eventually reach the town of Crownpoint water supply system. This situation is very analogous to a factory (or another town) using and returning water to a surface water body immediately upstream of a community which is using the same surface water body as a source of drinking water.

To determine whether groundwater degraded by ISL mining activities, even after restoration for both of the Unit 1 and the Crownpoint sites, could threaten the town of Crownpoint water supply, NRC staff evaluated three alternatives for the Unit 1 and Crownpoint sites:

1. No restoration of the groundwater after mining.
2. Restoration to secondary restoration goal.
3. Restoration to primary restoration goal.

In evaluating these alternatives, it was assumed for all parameters where pre-mining baseline values are below EPA water quality standards that future public water supply wells would be located within the well fields of both the Unit 1 and Crownpoint sites. Therefore, if a scenario is found to be acceptable for these parameters, it should be acceptable with respect to future impacts on the water quality at the existing town of Crownpoint water supply wells.

However, for those parameters where pre-mining baseline might exceed EPA water quality standards, NRC conducted a modeling study to determine the projected impact on water quality at the existing town of Crownpoint water supply wells. This approach was taken because if pre-mining baseline values exceed federal drinking water standards, the well field would be restored to pre-mining baseline averages. If these well field baseline concentrations are greater than baseline concentrations at the town water supply wells, then the previous assumption that acceptable restoration of the well field equals acceptable water quality impacts at the town wells cannot be made. Therefore, additional analysis for these parameters was done. An inspection of pre-mining baseline data revealed that this situation only exists for radium and uranium.

Table 4-10 contains a projected list of water quality concentrations in a well field at the end of mining, but prior to restoration activities in either the Unit 1 or Crownpoint sites. This situation represents the alternative of no groundwater restoration after mining. From an inspection of projected post-mining water

Table 4-10. Comparison of proposed restoration standards dated 9-19-96 to State and Federal Standards

Parameter	No restoration	Secondary goal alternative (mg/l)	Primary goal alternative (mg/l)
Parameters with primary standards			
Arsenic	C.054	0.05	0.0
Barium	0.1	2.0	0.05
Cadmium	0.01	0.01	0.0
Chromium	0.02	0.05	0.0
Fluoride	0.3	4.0	0.35
Lead	0.005	0.05	0.0
Mercury	0.0	0.002	0.0
Nickel	0.09	0.1	0.0
Nitrate	0.17	10.0	0.05
Radium-226[a]	150.0	5.0	65.85
Selenium	4.6	0.05	0.0
Uranium	33.5	BL	0.001
Parameters with secondary standards			
Sulfate	1,176.0	250.0	54.9
Chloride	317.0	250.0	10.9
Copper	0.04	1.0	0.0
Iron	0.02	0.3	0.0
Manganese	5.85	0.05	0.0
TDS	5,500.0	500.0	367.8
pH[b]	7.2	6.5–8.5	9.0
Parameters without EPA standards			
Boron	0.2	BL	0.06
Molybdenum	62.0	BL	0.0
Ammonia	1.07	BL	0.03
Calcium	320.0	BL	2.68
Magnesium	21.6	BL	0.44
Sodium	1,600.0	BL	120.3
Potassium	7.0	BL	10.58
Carbonate	0.0	BL	26.42
Bicarbonate	1,005.0	BL	201.22
Vanadium	0.48	BL	0.0

[a]pCi/l.
[b]Unitless.

BL = pre-mining baseline well field average. Same as average baseline alternative.

concentrations, it can be seen that radium-226, selenium, uranium, sulfate, chloride, manganese, total dissolved solids, and molybdenum greatly exceed both State of New Mexico and EPA drinking water standards. Therefore, without restoration, water quality would be degraded to the point that the groundwater could not be used as a source of drinking water without treatment.

The second alternative to be examined is groundwater restoration to secondary restoration goals. Health impacts analyses have been conducted for the EPA primary and secondary standards and, therefore, the impact of restoring groundwater quality to these concentrations should preserve the water use of the aquifer. The restoration of uranium to 0.44 mg/l should not be a threat to public health. This concentration was derived from the concentration of 300 pCi/ml listed in Appendix B of 10 CFR § 20, which identifies a concentration of 300 pCi/ml (0.44 mg/l) for unrestricted release of natural uranium to water.

The third alternative to be examined assumes that groundwater quality would be returned to the primary goal of restoration to pre-mining well field baseline averages. Table 4-10 contains average water quality concentrations for the Crownpoint site. With the exception of radium, all of these concentrations are below EPA primary and secondary standards. Therefore, restoring groundwater quality to these concentrations should preserve the water use of the aquifer.

However, the average baseline for radium at the Crownpoint site is calculated to be 65.85 pCi/L. This concentration exceeds both state (30 pCi/L) and federal standards (5 pCi/L). At the town of Crownpoint wells, radium-226 baseline values range from 0.18 to 0.2 pCi/L (HRI 1995b). Therefore, NRC staff conducted a modeling exercise to determine if restoring to these concentrations was acceptable at the town of Crownpoint wells.

The amount of dilution from groundwater flow (advection) and well head dilution was modeled. As a first step, NRC staff reviewed the modeling results submitted by HRI (Reed 1993). The HRI model calculated that it would take 35.6 years for groundwater to flow from the boundary of the Crownpoint site in Section 29 (east of town) to well BIA-6; 90.4 years from the boundary of the Crownpoint property in Section 19 (west of town) to well NTUA-1; and 1,657.5 years from the eastern most Unit 1 site boundary in Section 14 to the town wells.

NRC staff note that calculated groundwater flow times of 35.6 and 90.4 years are time periods within which it is quite likely that the town of Crownpoint could still be using water from the Westwater Canyon aquifer in the present area of the town wells. However, these time periods are also long enough that the pollution impact of the proposed mining operation would occur long after restoration activities had finished, making corrective action by HRI impossible.

From an analysis of material submitted by HRI, it can be seen that contamination from both the Crownpoint and Unit 1 sites would flow into wells NTUA-1 and BIA-6. Further, since the groundwater flow pathways from both sites are converging on the town wells, advective forces do not contribute to dilution.

Dilution is possible at the well head if uncontaminated water flows into the well from other directions. In this case, the uncontaminated water would dilute (reduce the concentration) of contaminates in the groundwater. An analysis of the groundwater flow pathways for the Crownpoint site indicates that well NTUA-1 receives only contaminated water and can take no dilution credit. However, well BIA-6 may pull

up to half of its water from an uncontaminated source. For the Unit 1 property, well NTUA-1 pulls about 60 percent of its water from an uncontaminated source and BIA-6 may pull as much as 70 percent of its water from an uncontaminated source.

In modeling the concentration of water quality parameters at the Crownpoint wells, NRC staff used baseline water quality to dilute the predicted post-restoration concentration by the amount estimated at the well head. Well head dilution was calculated for three scenarios: (1) radium-226 movement from the boundary of the Crownpoint property in Section 19 (west of town) to well NTUA-1; (2) radium-226 movement from the boundary of the Crownpoint site in Section 29 (east of town) to well BIA-6; and (3) radium-226 movement from the eastern most Unit 1 site boundary in Section 14 to well NTUA-1. It was observed that the combined effect of both the Unit 1 and Crownpoint sites on modeled well head concentrations should be no worse than the modeled concentrations at well NTUA-1 from the Crownpoint site alone.

Since no dilution was allowed in modeling the movement of radium from the Crownpoint site to well NTUA-1, modeled radium concentrations remained at 65.85 pCi/L. The model of radium-226 movement from the Crownpoint site to well BIA-6 allowed some dilution at the well head, which resulted in predicted concentrations of 33 pCi/L. For the Unit 1 site alone, modeled well head dilution effects were similar to the analysis for the Crownpoint site and well BIA-6 and resulted in radium-226 concentrations of 31 mg/l. Modeled concentrations of radium for all three scenarios of water movement to the town of Crownpoint well exceeded both State of New Mexico and EPA drinking water standards.

The preceding analysis assumes that dissolved constituents in the groundwater do not chemically react with solid material in the aquifer. For many water quality parameters this is unrealistically conservative. To investigate the role that geochemical interactions may have on modeled concentrations of radium-226 at the well head, the geochemical process of adsorption was investigated. One of the common methods used to model geochemical absorption is through the use of the distribution coefficient commonly known as K_d (Freeze 1979). The K_d approach attempts to predict the partitioning of solutes between the liquid and solid phases in a porous medium. For radium, a K_d reflective of reducing conditions was chosen because a reducing redox state creates conditions that make radium more mobile. Current groundwater flow modeling indicates that groundwater from the Crownpoint or Unit 1 site could flow through either the reduced or oxidized side of the roll front, or both. Radium K_ds for oxidizing environments fall in the 500 ml/g (Sheppard 1990; Allard 1979; Krishnaswami 1982; Serene 1982; Meijer 1995; Wescott 1995; Barney 1984). For reducing conditions in sandstone with low organic matter, Barney (1984) determined a Radium-226 K_d of 55 mg/l. It was this lower K_d that was used to model the retardation of radium-226 and gross alpha.

The modeled scenario of radium movement from the Crownpoint site to well NTUA-1 produced a travel time of 41,505 years. For the scenario of contaminant movement from the Crownpoint site to well BIA-6, radium had a travel time of 16,481 years. For the scenario of contaminant movement from the Unit 1 site to well NTUA-1, radium had a travel time of 758,535 years. Calculated travel times of these lengths indicate that for all practical purposes these parameters are immobile and would not reach the town wells in sufficient concentrations to exceed either State of New Mexico or EPA drinking water standards.

Uranium concentrations in the groundwater beneath the Crownpoint site average 0.001 mg/l, and at the town of Crownpoint wells range from 0.0006 mg/l to 0.003 mg/l (HRI 1995b). These concentrations are

well below both the NRC concentrations for uranium contained in 10 CFR § 20 and the EPA proposed maximum concentration limit for uranium. However, the calculated average concentration for uranium may be a function of the placement of the current wells relative to the ore body. At the Church Rock site, an average uranium concentration of 1.8 mg/l is calculated. When wells are located within the ore body it is possible that some well fields may have average uranium baseline values that exceed 0.44 mg/l. This raises the concern that uranium could migrate to the town of Crownpoint wells. To address this concern, NRC staff conducted the same modeling exercise for uranium that was conducted for radium.

Uranium is a cation that is least susceptible to chemical adsorption in oxidizing high bicarbonate environments (i.e., the conditions produced by ISL uranium mining). Therefore, after ISL mining, the dissolved uranium should be in uranium's most mobile form for oxidizing environments. As a result, uranium was assigned a K_d of zero in these transport calculations.

Since uranium could take either reducing or oxidizing pathways to the town water supply wells, for modeling purposes it was assumed that oxidizing conditions existed all the way to the town wells. Therefore, for the scenario of uranium movement from the boundary of the Crownpoint site in Section 19 (west of town) to well NTUA-1, uranium concentrations at the well head would be above the 0.44 mg/l. For the other two scenarios, any concentration that exceeded 0.93 mg/l would exceed a concentration of 0.44 mg/l. However, the Unit 1 calculation assumes that uranium would move entirely through oxidized rock. The modeled groundwater flow paths from the Unit 1 site into the reduced side of the ore body, the distance (2 miles) from the town wells, and the average travel time (1,657 years) would strongly suggest that the assumption that uranium would not encounter reducing conditions or other adsorption mechanisms between the town of Crownpoint is probably unduly conservative. In reality, it is reasonably certain that uranium concentrations should be significantly reduced in concentration before water from the Unit 1 site reaches the Crownpoint wells.

HRI modeled drawdown effects due to mining and restoration activities from the combined effect of the Crownpoint and Unit 1 sites (HRI 1996c). The model was developed to simulate a mine plan that used the maximum amount of groundwater removed for the 21-year period. Model runs were long enough so that drawdown effects were changing very slowly with time. Therefore, HRI believes that the model runs for the Crownpoint and Unit 1 sites represent the practical maximum drawdown effects that would occur.

The cumulative drawdown at the end of 21 years of mining at both Unit 1 and Crownpoint is projected as 55 feet on well NTUA-1 (49 to 55 feet for the area of the town wells). The maximum projected drawdown from the two sites is anticipated to occur after 17 years, and would produce a drawdown effect of 80 feet on well NTUA-1 (70 to 80 feet for the area of the town wells).

HRI observes that an adequate water column exists in the Crownpoint area to assure that the well yields of the town of Crownpoint wells would not be affected with even the worst case drawdown (i.e., if the current water column is 1,500 feet, then 1,420 feet would still be available). HRI concludes that the submersible pumps in the town wells would actually need to be lowered as a result of the projected drop in well water levels. However, if additional pipe is needed to lower a submersible pump in a town well, HRI estimates a one time cost of $5,000 for this work. This cost is conservative, because the additional pipe would normally be added during routine well servicing at the nominal cost of the pipe.

A drop in fluid levels could also result in increased pumping costs. HRI generated worst-case calculations based on the well which is projected to be most affected by a drop in water level during groundwater restoration activities at the Unit 1 and Crownpoint sites. Based on the projected impact at this well, HRI provided calculations to show the increased pumping costs from the lower projected water levels at town of Crownpoint wells BIA-3, BIA-5, BIA-6, NTUA-1, and NTUA-2. The additional annual cost due to groundwater restoration activities at the Crownpoint site was calculated to be $3,023. The additional annual cost due to groundwater restoration activities at the Unit 1 site was calculated to be $1,443. Therefore, the additional annual cost due to groundwater restoration activities at the Crownpoint and Unit 1 sites was calculated to be $4,466.

Based on these calculations, NRC staff conclude that water level drawdowns caused by restoration activities at the Crownpoint and Unit 1 sites could result in a one-time cost of $5,000 per well for a total of $25,000. Worst case pumping costs during groundwater restoration activities could range from $1,443 per year to $4,466 per year. Groundwater restoration activities at the Crownpoint site could result in a one-time cost of $25,000 and a pumping cost of $3,023 per year. Groundwater restoration activities at the Unit 1 and Crownpoint sites could result in a one time cost of $25,000 and a pumping cost of $4,466 per year.

Groundwater Mitigation. Restoring groundwater quality to EPA primary and secondary drinking water quality standards and to baseline values would allow the continued use of the groundwater and would not pose any significant health risks. If uranium is not restored to values less than 0.44 mg/l at the Crownpoint site, uranium concentrations may exceed this value at the town of Crownpoint wells.

NRC has yet to approve of the successful restoration of a production-scale well field at any of its licensed sites. Further, site-specific tests conducted by HRI have not demonstrated that the proposed restoration standards can be achieved at a production scale. Therefore, staff recommends that prior to the injection of lixiviant (i.e., prior to the extraction of uranium) at either the Unit 1 or Crownpoint site, HRI conduct a restoration demonstration at the Church Rock property. The demonstration should be conducted at a large enough scale that production-scale groundwater restoration is demonstrated.

In addition, staff recommends that prior to the injection of lixiviant at the Unit 1 site, HRI provide bonding to cover the cost of town well replacement, pipeline construction, and compatibility costs between the BIA and NTUA public water supply systems. With bonding, if HRI fails to achieve worst case restoration objectives or the town water supply is seriously threatened by an excursion, the local community would have the financial capability to develop and obtain a water supply system of equal water quantity and quality that is below EPA primary and secondary standards.

Staff recommends that prior to the injection of lixiviant at the Crownpoint site, HRI replace the town water supply wells, construct a water system pipeline, and provide funds so that the NTUA and BIA water supply systems can be connected. The replacement water supply wells should be located so that the town of Crownpoint continues to have a water supply system of equal quantity and a quality that can be maintained below EPA primary and secondary drinking water standards and 0.44 mg/l uranium. Further, the existing town wells should be abandoned and sealed so that they cannot become future pathways for the vertical movement of contaminants. This recommendation would mitigate potential impacts to the town of Crownpoint water supply system from post-restoration uranium migration to the town of Crownpoint wells and threats from potential excursions. Replacing the wells would prevent the degradation of the town of

Crownpoint water supply by any potential post-restoration groundwater contamination by uranium or other contaminants. HRI has committed to

> "replacement of any existing Town of Crownpoint water wells if needed, because of regulatory concern with the proximity of those wells to HRI's in situ mining operation. Wells would be moved beyond a minimum distance from active in situ mining operations, as agreed upon by the regulatory authorities in discussions with the company" (HRI 1996h).

When groundwater restoration activities begin at a production-scale well field at either the Unit 1 or Crownpoint site, staff recommends that HRI bond for the projected increased pumping and well work-over costs that might be incurred by the town of Crownpoint. This requirement does not include smaller restoration demonstration well fields.

4.3.1.2 Unit 1

Groundwater Impacts of Land Application. Groundwater contamination is not expected to occur in the Section 12 land application area because radionuclide concentrations (radium, uranium, and thorium) in the restoration water would be reduced to levels that could be released to surface water bodies and because the water table (groundwater) is at least 300 feet below the surface. Groundwater impacts from the Unit 1 facility alone would be less than the combined effect of disposing of restoration water from both the Crownpoint and Unit 1 sites.

Groundwater Impacts of ISL Mining. For the purpose of this environmental impact assessment, NRC staff assume that the flow direction in the Dakota Sandstone beneath the Unit 1 site is toward the town of Crownpoint. This assumption is based on the conservative view that the greatest potential for impact from the proposed project would be at the location of greatest groundwater use and human population.

As at the Crownpoint site, the potential to detect horizontal excursions at the Unit 1 site should be high. However, the potential for horizontal excursions should be less than at the Crownpoint site because the Unit 1 site is located further (2 miles) from the town of Crownpoint water wells. Therefore, there should be little effect from variations in pumping rates on water levels at the Unit 1 site and, with a properly balanced well field, the occurrence of horizontal excursions should be low. However, staff recommends that prior to the injection of lixiviant at either the Unit 1 or Crownpoint sites, HRI provide bonding to cover the cost of town well replacement, pipeline construction, and compatibility costs between the BIA and NTUA public water supply systems.

HRI has submitted data from the Unit 1 site collected in 1982, showing a difference of 192.13 feet in water levels between the Dakota Sandstone and the Westwater Canyon. Mobil conducted a long pump test of 24 hours duration in August 1982, in the Westwater Canyon aquifer in Sections 16 and 15, T17N R12W. Two wells were completed into the overlying Dakota Sandstone and showed no drawdown response during the pump test. Further analysis showed that leakage through the overlying Brushy Basin shale was not measurable (Prickett 1983; HRI 1996c). These data indicate that in the northeast corner of the Unit 1 site, the Westwater Canyon aquifer is not hydraulically connected to the Dakota Sandstone aquifer.

For the Unit 1 site, HRI purchased Mobil Oil Company's records which, to the best of HRI's knowledge, contain all plugging reports (HRI 1996a). Drilling at the Unit 1 site began in the early 1970s; therefore, all

plugging at the site was in compliance with the New Mexico State Engineers Regulation NMSA, Section 69-3-6. Having the surveyed locations of old exploration boreholes means that the holes would be easy to locate and plugged should one be suspected of leaking. Having the completion records for these holes increases the confidence that the holes were sealed correctly and should not leak during ISL mining activities.

Given the projected thickness and rock type of the overlying confining units, there should be little likelihood that any faults in the Unit 1 site would act as vertical pathways for groundwater migration from the mining zone to an overlying aquifer. The overlying confining unit consists of weakly indurated clay and shale, so that there is little potential for faults to act as vertical pathways (i.e., the faults are less likely to be open) for groundwater migration to an overlying sand. However, the potential for faults to act as vertical pathways is not non-existent. This is because stratigraphic observations cannot detect a fault if it has minor stratigraphic displacement or determine if the fault is open to groundwater flow. Therefore, HRI would conduct pre-mining tests to confirm aquifer confinement. Premining tests for confinement at the Unit 1 site would be the same as those described for the Crownpoint site.

The potential for vertical excursions at the Unit 1 site is very low because of the thick aquitards over and under the production zone and the quality of the plugged exploration holes and because of the future proposed integrity testing that would be applied to all wells (HRI 1996a). To detect leaks, HRI proposes to monitor water levels and water quality in the overlying aquifer. Further, in the event of a vertical excursion, HRI proposes to proceed immediately to determine the cause of the leakage and reverse the trend (HRI 1996a).

Thus, given the site geology, the previous borehole sealing procedures, and HRI's planned well integrity testing program, the risk of a vertical excursion occurring should be low. Three of the town of Crownpoint's water wells (BIA-5, BIA-3, and BIA-6) and a local well (Mobil Monument Windmill) located 0.5 mile east of the Crownpoint site in Section 28 (T17N R12W) are completed in the Dakota Sandstone. However, these wells are two miles from the Unit 1 boundary and should not produce a strong gradient at that distance. This means that the advective and dispersive forces from the point of leakage into the upper aquifer would not be as influenced by the local groundwater gradient. This in turn would allow the plume to spread and increase the potential for vertical excursion detection. Therefore, should an excursion go undetected it should be small in size.

In the Westwater Canyon, which is under the pumping influence of five large public water supply wells, HRI has modeled that it would take 1,657 years for water to flow from the Unit 1 site to the Town of Crownpoint. Therefore, any flow of groundwater in the Cow Springs aquifer or the Dakota Sandstone aquifer towards the town of Crownpoint should take much longer. However, it is recommended that prior to the injection of lixiviant at the Unit 1 site, HRI provide bonding to cover the cost of town well abandonment and replacement for the wells BIA-3, BIA-5, and BIA-6, which are open to the Dakota Sandstone. Bonding would mean that if the town water supply is seriously threatened by a vertical excursion into the Dakota sandstone, the local community would have the financial capability to develop and obtain a water supply system of equal quantity and quality.

Groundwater Monitoring. At the Unit 1 site, the Brushy Basin member does not contain any aquifers and consists entirely of shale (HRI 1996a). Above the Dakota Sandstone is 600–700 feet of Mancos Shale. Thereafter, to the surface a number of sands form the Mesa Verde Group, the lowermost being the Gallup

Sandstone. HRI proposes to monitor only the Dakota Sandstone with monitor wells spaced at a density of one per four acres (HRI 1996c).

However, while HRI does not propose to place monitor wells in the deepest saturated sands of the Mesa Verde Group, if a vertical excursion is confirmed in the Dakota Sandstone at the Unit 1 site, HRI would construct one or more exploration wells into the Mesa Verde (Gallup Sandstone) at the location where the excursion was identified (HRI 1996c).

NRC staff agree with HRI's determination that routine monitoring is warranted in the Dakota Sandstone, but that routine monitoring of the shallower Mesa Verde Group is not necessary. NRC staff find this approach acceptable because of the thick, laterally extensive Mancos shale separating the two systems and because the aquifers above the Dakota Sandstone at the Unit 1 site are relatively poor producers of groundwater. Therefore, the potential likelihood of a vertical excursion into the overlying aquifers is primarily through inadvertent leakage from installed wells. Mechanical integrity tests of injection and pumping wells provide an additional measure of safety to prevent vertical migration of injected fluids from wells. However, should a vertical excursion occur, NRC would require that any significant aquifer above the Dakota sandstone aquifer be explored for vertical excursions as opposed to just the deepest saturated sand of the Mesa Verde Group.

As previously described, no monitoring would be conducted in the underlying Cow Springs aquifer (HRI 1996a). The Cow Springs aquifer is separated from the Westwater Canyon aquifer at each of the three sites by the Recapture Shale, which is estimated to be about 79 m (260 ft) thick at the Unit 1 site. A large number of holes were drilled into the Recapture Shale at each of the three sites; however, most of these holes only penetrated the upper 1.5 m to 12 m (5 to 40 ft). None of the holes penetrated the entire thickness of the Recapture Shale (HRI 1996c). From an inspection of the materials submitted in the license application, NRC staff have not found any instances where this unit is absent beneath the site. Due to the thickness of the Recapture Shale and the low potential that drill holes within the site boundary have penetrated the Recapture Shale, there should be little risk of a vertical excursion into the Cow Springs aquifer.

The nearest wells completed in the Cow Springs aquifer are town of Crownpoint well BIA-5 and a local well (Mobil Monument Windmill) located 0.5 mile east of the Crownpoint site in Section 28 (T17N R12W). Monitoring of water quality in the Cow Springs aquifer at the Unit 1 site is not required because the potential for a vertical excursion into the aquifer is low and because pumping by the windmill east of town and by well BIA-5 should have only a small influence on the rate of water movement in the aquifer. In the Westwater Canyon, with its expected higher permeabilities and the influence of five large public water supply wells, HRI has modeled that it would take 1,657 years for the water to flow from the Unit 1 site to the town of Crownpoint. Therefore, should a vertical excursion occur in the Cow Springs aquifer, any flow of groundwater in the Cow Springs aquifer towards the town of Crownpoint should take much longer than the rate of flow in the Westwater Canyon aquifer.

Groundwater Restoration. Potential impacts due to decreases in water levels at the town of Crownpoint wells from groundwater restoration activities at the Unit 1 site are described above in the Groundwater Restoration subsection for the Crownpoint site. Restoration activities at the Unit 1 site could result in a one-time cost of $25,000 and a pumping cost of $1,443/yr.

Groundwater Mitigation. Staff recommends that prior to the injection of lixiviant at either the Unit 1 or Crownpoint sites, HRI provide bonding to cover the costs of replacing town wells BIA-3, BIA-5, and BIA-6 and of constructing new pipelines, as needed, to ensure compatibility between the BIA and NTUA public water supply systems.

When groundwater restoration activities begin at a production-scale well field at either the Unit 1 or Crownpoint sites, staff recommends that HRI bond for the projected increased pumping and well work-over costs that might be incurred by the town of Crownpoint. This requirement does not include smaller restoration demonstration well fields.

4.3.1.3 Church Rock

Groundwater Impacts of Land Application. HRI's potential land application areas for the Church Rock site (Sections 17 and 16) are located on top of the Mancos shale. Therefore, land application should pose no threat to groundwater quality in the underlying aquifers. The two areas, which are located above the Church Rock site on flat mesa land, should pose no threat to any regional aquifers and could, at most, influence small perched water bodies that might form within the mesa.

Groundwater Impacts of ISL Mining. Mine tunnels completed into the Westwater Canyon aquifer exist in the southern end of the Church Rock site. HRI plans to conduct ISL mining operations in the area of these tunnels, most of which are believed to be intact and not collapsed (HRI 1996a). HRI has reviewed the mine workings (tunnels) mapped by the previous operator and concluded that no workings extend beyond the boundaries of the planned well fields (HRI 1996a; HRI 1996c).

As at the Crownpoint site, the potential to detect horizontal excursions at the Church Rock site should be high. Monitor wells would encircle the well field and the mine workings to detect horizontal excursions should they occur. With a properly balanced well field, the potential for horizontal excursions should be low. HRI provided aquifer modeling results that demonstrate that the project could be conducted while controlling lixiviant migration (HRI 1996c). The model was run using site data on the hydraulic characteristics of the Westwater sandstone and HRI's projected operational data. The results of the model indicate that a cone of depression would be formed during the project. A groundwater divide would develop between each mine unit and locations down-gradient during the production and restoration phases of the project. Therefore, groundwater and lixiviant migration would be controlled by forcing water to flow into the well fields.

However, HRI's model did not include the mine tunnels in it's design. Since the tunnels would be inside the well field, most of the hydrologic effects of the tunnels on the lateral movement of groundwater should be internal to the well field. As a result, if the outer ring of injection or production wells are outside the tunnel area, the potential for lateral excursions by a properly balanced well field should be low. However, at this time HRI has not provided NRC with detailed well field designs. For ISL mining applications, this information is usually developed after the license is issued and as mining sequentially progresses over the property. Nevertheless, ISL uranium mining in areas with preexisting tunnels is a unique situation. Therefore, to provide additional assurance that excursions can be controlled, staff recommends that prior to mining in the area of tunnels HRI conduct a modeling demonstration of planned well fields to confirm that they can be properly operated in the presence of the preexisting tunnels without causing horizontal excursions. In addition, the detection of vertical excursions would require increased attention because the

existing shafts provide direct communication between the mine zone and the upper aquifers. Therefore, prior to mining in the area of tunnels staff recommends that HRI provide a report to the NRC explaining how the upper aquifer monitor well locations would provide adequate coverage for the well field as well as the area around the vertical shafts.

In January 1988, HRI conducted a pump test in the Westwater Canyon at the northern end of the Church Rock site (HRI 1993a). In addition to the Westwater Canyon aquifer, a well was completed in the Brushy Basin "B" sand and the Dakota Sandstone aquifers. A Westwater Canyon aquifer well was pumped for 72 hours, during which communication between the Westwater Canyon aquifer and the overlying aquifers was not detected. These data indicate that in the area of the pump test the Westwater Canyon aquifer is not hydraulically connected to either of the overlying aquifers.

HRI has exploration drill hole survey locations for all exploration holes drilled at the Church Rock site (HRI 1996a). The Church Rock site was drilled before the modern plugging requirements of the New Mexico State engineer were promulgated (1968), and therefore the holes are plugged with old drill mud and geologic materials that have collapsed into some holes. The confining units at the Church Rock site contain clays and shales, and the plugging of boreholes from clays squeezing the boreholes shut was a consistent problem at the Church Rock site (HRI 1996a). The pressure that this natural plugging would contain is extremely difficult to quantify, but nonetheless is real. From discussions with personnel of the previous mine owner (United Nuclear Corporation), HRI states that old drill holes in the underground tunnels, plugged only with drilling mud, did not allow water to flow into the mine (HRI 1996a). It was further related that except for a slight discoloration in the old drill hole itself, it was difficult to tell where a hole was intersected by a mine tunnel.

During ISL mining, vertical pathways for groundwater flow could be caused by collapsing tunnels. If a tunnel collapse occurs during mining, vertical pathways could be created as the overlying rock layers collapse into the tunnel or the collapse causes well casings to break. In addition, ISL mining could increase the potential for tunnels to collapse. Tunnel walls that are near an injection well would experience an increase in pressure; those that are near a production well would experience a decrease in pressure. Thus, the tunnel as a whole may experience a range of varying pressures as mining proceeds through a well field.

HRI does not propose to drill any wells through old tunnel workings. However, should HRI determine that it is economically feasible to mine reserves under the mine workings through ISL, HRI would drill and complete wells through the mine workings or directionally drill and complete wells from the mine tunnels. If wells are drilled and completed through the workings, HRI would use two strings of casing through the mine workings, one casing string inside the other. Surface casing would first be installed and would extend into the sand/clay below any tunnels that the bore-hole intersects. This surface casing would be of sufficient strength that it would support at least 150 percent of the expected maximum pressures that might be placed on it, either burst or collapse. As with a normal well installation, this surface casing would be grouted to the surface, except across any open mine workings. Drilling would then continue until final depth is reached. The well casing normally used in well completions would then be installed inside the surface casing and grouted to the surface. There would be two strings of casing with two grout barriers throughout the well completion, except for across the mine tunnels (approximately 9 feet in height), which would have two casing strings and one grout barrier.

Given the projected thickness and rock type of the overlying confining units, there should be little likelihood that any faults in the Church Rock site would act as vertical pathways for groundwater migration from the mining zone to an overlying aquifer. HRI has not discovered any faults within the Church Rock site (HRI 1993a). The overlying confining unit consists of weakly indurated clay and shale, so that there is little potential for faults to act as vertical pathways (i.e., the faults are less likely to be open) for groundwater migration to an overlying sand. However, the potential for faults to act as vertical pathways is not non-existent. This is because stratigraphic observations cannot detect a fault if it has minor stratigraphic displacement or determine if the fault is open to groundwater flow. Therefore, HRI would conduct premining tests to confirm aquifer confinement. Premining tests for confinement at the Church Rock site would be the same as those described for the Crownpoint site.

Given the thick aquitards over and under the production zone, the planned well integrity testing program, and the potential for old boreholes to squeeze shut, the risk of a vertical excursion occurring outside the area of former mining activities should be low. To detect leaks, HRI proposes to monitor water levels and water quality in the overlying aquifer. Further, in the event of a vertical excursion, HRI proposes to proceed immediately to determine the cause of the leakage and reverse the trend (HRI 1996a). As discussed for the Unit 1 site, the potential for an upper aquifer excursion to go undetected should be small and should one go undetected it would most likely be small in size.

In the area of the shaft and tunnels, the potential for vertical excursions to occur is greater. However, it should be possible to mine in the Westwater Canyon aquifer and not create a vertical excursion. This can be accomplished by sealing off the shafts or structuring well field pressures so that in the area around the shafts they are less than overlying aquifer pressures. However, HRI has not specifically demonstrated how this would be accomplished.

In recognition of the increased potential for vertical excursions to occur, HRI proposes to place monitor wells in locations where raises from the existing mine workings in the Westwater Canyon penetrate the confining shales/clays. In addition, monitor wells would be placed at the standard density in unaffected Brushy Basin "B" Sand adjacent to the shafts.

The Cow Springs aquifer is separated from the Westwater Canyon aquifer at each of the three sites by the Recapture Shale, which is estimated to be about 55 m (180 ft) thick at the Church Rock site. A large number of holes were drilled into the Recapture Shale at each of the three properties. However, most of these holes only penetrated the upper 1.5 m to 12 m (5 to 40 ft). None of the holes penetrated the entire thickness of the Recapture Shale (HRI 1996c). From an inspection of the materials submitted in the application, NRC staff have not found any instances where this unit is absent beneath the site. Due to the thickness of the Recapture Shale and the low potential that drill holes in the site boundary have penetrated the Recapture Shale, there should be little risk of a vertical excursion into the Cow Springs aquifer.

HRI modeled drawdown effects for the Church Rock site. The model was developed to simulate a mine plan that used the maximum amount of groundwater removed for the 21-year period. Model runs were long enough so that drawdown effects were changing very slowly with time. Therefore, HRI believes that the model runs for the Church Rock site represent the practical maximum drawdown effects that would occur. This model produced a decline in water levels at the most down-gradient monitor well (MW-20) that ranged from approximately 12 to 34 feet during the mining and restoration phases of the project (Reed 1993).

Groundwater Monitoring. At the Church Rock site, HRI proposes to monitor the Brushy Basin "B" sand as well as the Dakota Sandstone aquifer (HRI 1996a; HRI 1996c). Above the Dakota Sandstone it is continuous Mancos Shale to the surface. Shallow monitor wells would be completed in the first and second aquifers overlying the ore zone. Upper monitor wells would be located at a minimum of one well per every four acres of production area for wells completed in the first overlying freshwater aquifer (Brushy Basin), and one per every eight acres for wells completed in any additional overlying fresh water aquifer (Dakota Sandstone) (HRI 1993a).

HRI does not propose to expand upper monitor well coverage in the area of previous mining. Instead, HRI proposes to locate monitor wells in a manner which would appropriately provide early detection of potential vertical excursions. HRI would place monitor wells specifically in locations where shafts from the existing mine workings in the Westwater Canyon penetrate the confining shales/clays. Monitoring at such locations would provide the earliest possible warning of interformational fluid migration. Additionally, monitor wells would be placed at the standard density in unaffected Brushy Basin sands adjacent to the raises (HRI 1996c).

As previously described, no monitoring would be conducted in the underlying Cow Springs aquifer (HRI 1996a).

Groundwater Restoration. HRI does not believe the existing mine tunnels would present a significant problem for groundwater restoration. HRI has presented data on total dissolved solids to support its opinion that water quality in the existing mine workings has been previously contaminated by conventional underground mining and, unlike native groundwater, does not meet primary drinking water standards for total dissolved solids (HRI 1996c). Therefore, HRI concludes that if the mine workings are affected chemically by ISL mining, they should require less restoration effort than the native sandstone leached in other areas (HRI 1996c). This is because with a poor background water quality, restoration to background or a water quality standard would be easier.

In addition, HRI estimates that the mine workings contain 2.9 million cubic feet or 22 million gallons of water, and that it would take only one pore volume to clean the ground water in the tunnels (i.e. one displacement of the water contained in the tunnels) (HRI 1996c). HRI bases this opinion on the observation that lixiviant interactions with the rock matrix in the mined sandstone should require additional flushing during restoration, as compared to the empty mine workings. HRI has also presented calculations (HRI 1996c) which show that a one pore volume restoration estimate for the tunnels is not materially greater than the amount of water that would have to be pumped through the rock to restore the groundwater if the tunnels were not there. HRI also proposes that any projected increased groundwater restoration costs would be provided for by adequate surety (HRI 1996c).

The existence of preferential flow paths and the water contained in the tunnels may create some unique restoration problems. For example, preferential pathways may mean less water flows through the matrix, inhibiting cleanup of the matrix. In addition, water in the tunnels may become contaminated. Since wells would not be directly monitoring the water quality in the tunnels, it is possible that contaminated water may be left behind in the tunnels. Restoring the tunnels to a poorer water quality than the water quality of the surrounding aquifer may make it difficult to restore the water in the surrounding aquifer (i.e., poorer water quality would be constantly pulled from the tunnels).

If HRI proposes to restore water in the tunnels to a different quality than water in the surrounding rock, HRI would be required to adequately characterize the premining quality of the shafts. At the end of mining, HRI would be required to adequately sample tunnel water quality to determine whether restoration goals in the tunnels and shafts have been meet. For purposes of impact analysis and surety calculation, it is assumed that water quality in the tunnels would be the same as the rest of the aquifer. In addition, a general restoration standard for cleanup of the surrounding rock based on tunnel water quality would not be allowed.

An active uranium ore body is one where reducing conditions exist on one side of the ore body and oxidizing conditions exist on the other side. Current research (Deutsch 1985; Deutsch 1983) indicates that for active ore bodies, the redox sensitive ions (such as uranium) which have been mobilized by uranium solution mining would rapidly be adsorbed and removed from groundwater when they encounter reducing conditions in the rock. So if the post-mining groundwater flow direction is from the oxidized side of the ore body to the reduced side, these ions should be rapidly attenuated after solution mining activities.

However, as recognized by HRI (HRI 1996a), the dewatering effects of the old mine tunnels have subjected the Westwater Canyon Member to oxidizing conditions. The implication is that for some distance around the old Church Rock mine working (i.e., into areas that were not mined by the underground operation) dewatering may have significantly diminished or eliminated reducing conditions in the aquifer. Therefore, uranium may move a longer distance than would normally be predicted before it encounters reducing conditions in the aquifer.

4.3.1.4 Regional and Cumulative

Assuming successful groundwater restoration, some water quality parameters in groundwater in mining areas would have been returned to background and some would be higher than background, but less than federal primary and secondary drinking water standards. The total volume of this water is estimated to be 3.3 million m^3 (2,671 acre-ft). This volume was calculated from pore volume and restoration volume data submitted by HRI (HRI 1996a). In calculating this value, the following assumptions were made:

1. Final constituent concentrations, on a well field average, would comply with the restoration standards established in the license.
2. No lateral or vertical excursions occurred during operations, or if they occurred, they were restored to pre-mining baseline quality.
3. The total amount of pore space within the mined portion of the aquifer at the well field represents the water available for consumption after restoration.
4. The porosity is 0.28 and the combined horizontal and vertical dispersion factors are 1.95.

For a 4 pore volume restoration approach, the water consumed over the life of the project at all three sites is estimated to be:

Water consumed

Restoration alternatives	Million m^3	Acre-feet
Groundwater sweep	12.9	10,525
Reverse osmosis	3.3	2,632
Brine concentration	0.03	24

If more than 4 pore volumes are needed, restoration water consumption would increase accordingly. The town of Crownpoint water supply wells would have to be abandoned and moved.

4.3.2 Alternative 2 (modified action)

4.3.2.1 Alternative Sites for ISL Mining

The Church Rock Site Only. For the Church Rock site only alternative, the volume of water restored to average background or less than federal primary and secondary drinking water standards is estimated to be 1.0 million m^3 (780 acre-ft). For a 4 pore volume restoration approach, the water consumed over the life of the project is estimated to be:

Water consumed

Restoration alternatives	Million m^3	Acre-feet
Groundwater sweep	3.4	2,792
Reverse osmosis	0.9	698
Brine concentration	0.009	7

The Unit 1 Site Only. For the Unit 1 site only alternative, the volume of water restored to average background or less than federal primary and secondary drinking water standards is estimated to be 0.8 million m^3 (644 acre-ft). For a 4 pore volume restoration approach, the water consumed over the life of the project is estimated to be:

Water consumed

Restoration alternatives	Million m^3	Acre-feet
Groundwater sweep	4.5	3,674
Reverse osmosis	[illegible]	919
Brine concentration	0.008	7

Should unsuccessful groundwater restoration or excursions seriously threaten water quality in the town of Crownpoint water wells, the town water wells would have to be abandoned and moved.

The Crownpoint Site Only. For the Crownpoint site only alternative, the volume of water restored to average background or less than federal primary and secondary drinking water standards is estimated to be 1.5 million m^3 (1,247 acre-ft). For a 4 pore volume restoration approach, the water consumed over the life of the project is estimated to be:

Restoration alternatives	Water consumed Million m^3	Water consumed Acre-feet
Groundwater sweep	5.0	4,059
Reverse osmosis	1.3	1,015
Brine concentration	0.013	10

Under this alternative, the town of Crownpoint water supply wells would have to be abandoned and moved.

The Church Rock and Unit 1 Sites Only. For the Church Rock and Unit 1 sites only alternative, the volume of water restored to average background or less than federal primary and secondary drinking water standards is estimated to be 1.8 million m^3 (1,424 acre-ft). For a 4 pore volume restoration approach the water consumed over the life of the project at both sites is estimated to be:

Restoration alternatives	Water consumed Million m^3	Water consumed Acre-feet
Groundwater sweep	7.9	6,466
Reverse osmosis	2.0	1,617
Brine concentration	0.02	14

The Unit 1 and Crownpoint sites only.

Should unsuccessful groundwater restoration or excursions seriously threaten water quality in the town of Crownpoint water wells, the town water wells would have to be abandoned and moved.

4.3.2.2 Alternative Sites for Yellowcake Drying and Packaging

Impacts to groundwater quantity and quality would be the same regardless of the alternative site selected for yellowcake drying and packaging.

4.3.3 Alternative 3 (no action)

Under the no action alternative, there would be no impacts to groundwater quantity or quality.

4.4 SURFACE WATER

4.4.1 Alternative 1 (the proposed action)

4.4.1.1 Crownpoint

All drainage channels near and at the Crownpoint site are ephemeral washes, which only contain water during infrequent periods of precipitation or snow melt. The facility would not discharge to drainage channels as a result of well field or plant operation. During periods of rainfall, well field construction and reclamation activities at the site may contribute a small amount of sediment to on-site drainage channels. After reclamation, the surface would be vegetated and contoured to prevent adverse effects to surface water quality. Any effect on water quality during infrequent periods of runoff is expected to be small and temporary. Land application sites would be operated to minimize the potential for off-site runoff. Precautions taken would include:

1. No irrigation during a rainfall event.
2. If heavy rains are forecast, no irrigation during the preceding 12 hours.
3. No irrigation on saturated soils.
4. No irrigation on steep slopes or soils shallower than 72 inches.

Contaminated material would not be released to drainage channels in the area as the result of impoundment failure. NRC staff would require HRI to apply the criteria of U.S. Regulatory Guide 3.11 on the *Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills*. In addition, staff would require that HRI show through detailed engineering analyses that the impoundments and diversion channels around the impoundments would be stable under a probable maximum flood condition, in accordance with NRC Staff Technical Position #WM-8201, *Hydrologic Design Criteria for Tailings Retention Systems*. Accordingly, HRI would be required to provide detailed analyses to document the adequacy of the system during an occurrence of the probable maximum flood. Analyses and hydraulic design computations would be reviewed by the staff for peak flows, peak velocities, and water surface profiles. In general, HRI has committed (HRI 1996c) to follow the guidance suggested in NRC Staff Technical Position *Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites*.

HRI has not provided detailed information regarding specific and unique details of the diversion channels or impoundment system. HRI has provided general information regarding the preliminary design layout of the facility and the potential for flooding of the site (HRI 1996e). This detailed information is needed before staff can judge the acceptability of the final design.

However, based on a review of the preliminary information provided by HRI (HRI 1996e), staff believes that there are no particularly unique design problems associated with the implementation and completion of the hydraulic design features of the Crownpoint site. NRC staff have visited the site area and have considerable experience in reviewing diversion channel and hydraulic designs. Based on that knowledge,

staff believe that an acceptable engineering design can be provided. When that design is provided, staff will evaluate its acceptability. Accordingly, staff recommends that a license condition requiring submittal of revised hydraulic design information and review/approval by the NRC be developed and incorporated into the license.

4.4.1.2 Unit 1

Projected surface water impacts for the Unit 1 site are nearly identical to the impacts described for the Crownpoint site (Section 4.4.1.1). Accordingly, staff recommendations for both sites are the same.

4.4.1.3 Church Rock

All drainage channels near and at the Church Rock site are ephemeral washes, which only contain water during infrequent periods of precipitation or snow melt. Projected impacts for the Church Rock site are nearly identical to the impacts described for the Crownpoint site (Section 4.4.1.1). The facility would not discharge to drainage channels as a result of well field or plant operation. However, the facility may discharge restoration water into surface water streams (HRI 1996a). This discharge might occur if groundwater sweep is chosen as a groundwater restoration option and enough water rights cannot be obtained to dispose of the water by land application. Should surface water discharge be implemented, HRI would have to obtain any appropriate state or federal permits.

Any effect on water quality during infrequent periods of runoff is expected to be small and temporary. Land application sites would be operated to minimize the potential for off-site runoff, as described for the Crownpoint site (Section 4.4.1.1).

Contaminated material would not be released to drainage channels in the area as the result of impoundment failure. NRC staff would require HRI to apply the criteria of U.S. Regulatory Guide 3.11 on the *Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills*. In addition, staff would require that HRI show through detailed engineering analyses that the impoundments and diversion channels around the impoundments would be stable under a probable maximum flood condition, in accordance with NRC Staff Technical Position #WM-8201, *Hydrologic Design Criteria for Tailings Retention Systems*. Accordingly, HRI would be required to provide detailed analyses to document the adequacy of the system during an occurrence of the probable maximum flood. Analyses and hydraulic design computations would be reviewed by the staff for peak flows, peak velocities, and water surface profiles. In general, HRI has committed (HRI 1996c) to follow the guidance suggested in NRC Staff Technical Position *Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites*.

HRI has not provided detailed information regarding specific and unique details of the diversion channels or impoundment system. HRI has provided general information regarding the preliminary design layout of the facility and the potential for flooding of the site (HRI 1996e). This detailed information is needed before staff can judge the acceptability of the final design.

However, based on a review of the preliminary information provided by HRI (HRI 1996e), staff believes that there are no particularly unique design problems associated with the implementation and completion of the hydraulic design features of the Church Rock site. NRC staff have visited the site area and have considerable experience in reviewing diversion channel and hydraulic designs. Based on that knowledge,

staff believe that an acceptable engineering design can be provided. When that design is provided, staff will evaluate its acceptability. Accordingly, staff recommends that a license condition requiring submittal of revised hydraulic design information and review/approval by the NRC be developed and incorporated into the license.

4.4.1.4 Regional and Cumulative

Due to the ephemeral nature of the surface water bodies in the area and the relatively low level of surface disturbance, there should not be any significant impacts on the quality or quantity of surface water from the combined operation of the three project sites.

4.4.2 Alternative 2 (modified action)

4.4.2.1 Alternative Sites for ISL Mining

Impacts for each of the alternative sites should be less than the impacts of the proposed project, which are predicted to be of little significance. The alternatives considered are:

1. The Church Rock site only
2. The Unit 1 site only
3. The Crownpoint site only
4. The Church Rock and Unit 1 sites only
5. The Church Rock and Crownpoint sites only
6. The Unit 1 and Crownpoint sites only

4.4.2.2 Alternative Sites for Yellowcake Drying and Packaging

Construction, operation, and decommissioning of a processing facility at either the Church Rock or Unit 1 site should have little effect on the quality or quantity of surface water.

Use of HRI's existing ISL facility at Kingsville, Texas, or the Ambrosia Lake Uranium mill, located north of Milan, New Mexico, should have no impact on the quality or quantity of surface water at either the site.

4.4.3 Alternative 3 (no action)

The no action alternative would result in no impacts to either surface water quality or quantity in the project area.

4.5 TRANSPORTATION RISK

4.5.1 Alternative 1 (the proposed action)

Materials transportation to and from the three project sites can be classified into three categories: (1) shipments of refined yellowcake from the Crownpoint processing facility to a uranium conversion

facility in Illinois; (2) shipments of yellowcake slurry or resin from the Unit 1 and Church Rock satellite facilities to the Crownpoint processing facility; and (3) shipments of process chemicals from suppliers to the three sites. Staff have conceptualized and analyzed a transportation accident in each of these three categories and the results are given in the following subsections.

4.5.1.1 Shipments of Packaged Yellowcake from Crownpoint to Illinois

Yellowcake produced by the proposed project would not differ in any significant way from yellowcake produced at a conventional uranium mill. Similarly, yellowcake shipments made from the proposed project would not differ in any significant way from those made from a conventional mill. NRC evaluated transportation accidents associated with yellowcake shipments from conventional mills and published the results in a generic environmental impact statement (NRC 1980b). The following analysis is based on that earlier study.

Refined yellowcake is generally packed in 55-gallon, 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 171-189 and 10 CFR 71). Yellowcake would be shipped by truck approximately 2400 km (1500 miles) to a conversion plant in Illinois, which would process the yellowcake in the first step of manufacturing reactor fuel. An average truck shipment contains approximately 40 drums, or 17 metric tons (19 tons) of yellowcake. Based on the projected maximum annual yellowcake production for the proposed project of 1360 metric tons (3 million lb), approximately 80 shipments of 40 drums each would be required annually when each of the three sites is producing at full capacity.

The average probability of a truck accident is 4.0E-7/km (6.4E-7/miles) on interstate highways in rural areas, 1.4E-6/km (2.2E-6/miles) on interstate highways in urban areas, and 1.4E-6/km (2.2E-6/miles) on two-lane roads typical of those in the vicinity of the proposed project (Harwood and Russell 1990). Truck accident statistics for the Crownpoint vicinity are presented in Section 3.4. The route to the conversion facility in Illinois is approximately 1920 km (1193 miles) on rural interstate highways and 480 km (1298 miles) on urban highways. Based on these statistics, the projected number of shipments per year, and the shipping distance, the likelihood of a truck from the proposed project being involved in any accident during a 1-year period is approximately 1 chance in 10 on the interstate portion and 5 chances in 1000 on New Mexico 371 and Navajo 9. Given a heavy truck accident, the probability of an injury is 0.21 and the probability of a fatality is 0.01 on the interstate portion (DOT 1995). The probability of an injury or fatality from an accident involving a truck carrying yellowcake on New Mexico 371 and Navajo 9 is about 1 chance in 1000 (0.001) during a 1-year period.

In a generalized accident-risk evaluation, NRC classified accidents into eight categories, depending on the combined stresses of impact, puncture, crush, and fire. On the basis of this classification scheme, conditional accident probability was developed for eight severity levels. These fractional probabilities of occurrence for truck accidents are given in column 2 of Table 4-11.

To assess the risk of a transportation accident, the fraction of radioactive material released when an accident of a given severity occurs must be known. For this analysis, two accident models are considered. Model I is hypothetical; complete loss of drum contents is assumed for all but the lowest accident severity category. Model II is based on actual tests; partial loss of drum contents is assumed. The yellowcake packages are Type A drums containing low specific activity (LSA) material. The fractional releases to the

Table 4-11. Fractional probabilities of occurrence and corresponding package release fractions for each of the release models for low specific activity (LSA) and Type A containers involved in truck accidents

Accident severity category	Fractional occurrence of accident	Release fractions	
		Model I	Model II
I	0.55	0	0
II	0.36	1.0	0.01
III	0.07	1.0	0.1
IV	0.016	1.0	1.0
V	0.0028	1.0	1.0
VI	0.0011	1.0	1.0
VII	8.5×10^{-5}	1.0	1.0
VIII	1.5×10^{-5}	1.0	1.0

Source: Nuclear Regulatory Commission 1977. *Final Environmental Report on the Transportation of Radioactive Materials by Air and Other Modes* (NUREG-0170).

environment for each model are shown in columns 3 and 4 of Table 4-11. Considering the fractional occurrence and the release fractions (loss) for Models I and II, the quantity of yellowcake released from the containers in the event of a truck accident is estimated to be 7700 kg (17,000 lb) for Model I and 520 kg (1140 lb) for Model II.

The previously stated probabilities of an accident can now be further defined: the probability of an accident producing a Model I release (upper bound) is 0.05 per year on the interstate system and 0.002 per year on New Mexico 371 and Navajo 9. The Model II accident probabilities (more realistic) are 0.004 per year on the interstate system and 0.0002 per year on New Mexico 371 and Navajo 9.

Most yellowcake released from the container would be deposited directly on the ground in the immediate vicinity of the accident. However, some fraction of the released material would be dispersed to the atmosphere. Using expressions for material dispersal to the environment (Battelle Northwest Laboratories 1975), the following empirical expression was derived for release from the container:

$$F = 0.001 + 4.6E\text{-}4\ (1 - e^{-0.15ut})\ u^{1.78}$$

where

F = the fractional airborne release,
u = the wind speed at 15.2 m (50 ft) expressed in m/s,
t = the duration of the release, in hours.

In this expression, the first term represents the initial "puff" that is immediately airborne when the container fails in an accident. Assuming the wind speed is 5 m/s (10 mph) and the time available for release is 24 hours, the estimated environmental release fraction would be 9E-3. A recent summary of data by DOE (1994) shows this value to be conservative by a factor of nearly 6. For insoluble uranium, all particles in the respirable size range, and a typical population density of 61 persons/km² (160 persons/ miles²) of the eastern United States, the 50-year dose commitments to the lungs of the general public would be about 2 man-Sv (200 man-rem) and 0.14 man-Sv (14 man-rem) for Models I and II, respectively. These values estimate the doses integrated over a 50-year time period following exposure. Population density for the eastern United States was used because yellowcake shipments would be sent to Illinois. Integrated dose estimates for more sparsely populated areas would be lower.

In an accident that occurred in September 1977 (NRC 1980b), a commercial carrier hauling 50 drums of uranium concentrate overturned and spilled an estimated 3200 kg (7000 lb) of yellowcake on the ground and in the truck trailer. Within 3 hours, the material was covered with plastic sheeting to prevent further release to the atmosphere. Using the formula given earlier for the 3-hour duration of release, an estimated 24 kg (53 lb) of ^{308}U were released to the atmosphere. The consequence for the area in which the accident actually occurred, where the population density is about 1.0 person/km² (2.5 persons/miles²), is estimated to be 0.012 man-Sv (1.2 man-rem).

Inhaling yellowcake dust might produce some health effects due to the chemical toxicity of uranium. In the case of the September 1977 accident, no clinical effects were observed among the individuals who were involved with the spill and subsequent cleanup. Also, uranium bioassays of 27 persons who were in the vicinity of the spill, including the law enforcement and rescue personnel, indicated that chemically toxic levels of uranium intake did not occur.

4.5.1.2 Local Transportation of Uranium Slurry

HRI's proposal to operate the Church Rock and Unit 1 facilities involves transporting yellowcake slurry or resins from the satellite processing facilities to the Crownpoint facility for processing, drying, and packaging. The slurry would be transported by truck from the satellite plants in specially designed 9900-L (2600-gal) stainless steel tanks with walls that are 0.65-cm (¼-in.) thick. Such tanker trucks would withstand the impact of most collisions. The truck accident rate per trip is 9.2E-5 from Church Rock and 6.6E-6 from Unit 1 (Section 3.4). The projected maximum annual yellowcake yield from both the Church Rock and Unit 1 facilities is 454 metric tons (1 million lb), and approximately 100 tank truck shipments per year would be the maximum required from each satellite site. Based on accident statistics and the projected number of annual shipments, the likelihood of a tank truck from the Church Rock site being involved in an accident during a 1-year period is 0.009. The likelihood of a fatality or injury from a uranium tank truck accident during a 1-year period is 0.002.

In the most severe conditions, an accident would result in a rupture of the tank and release of only a portion of the slurry. During such an accident, slurry would pour onto the ground and thicken as water in the slurry soaked into the ground. Eventually, some slurry would dry, and yellowcake could be released to the atmosphere near the spill, depending on the time required to clean up the material.

The effects of accidents involving wet yellowcake would be considerably less than those involving yellowcake dust as described in Section 4.5.1.1 because the material would be incapable of becoming

airborne as dry dust. To prevent the spread of contamination, HRI would be responsible for cleaning up the slurry as rapidly as possible. Oversight would be provided on-site by an NRC inspector through NRC's regional office and by the Incident Response Center and would be coordinated with state and local emergency assistance teams.

Sufficient statistical data are not available for a quantitative analysis of the consequences of such an accident. However, the consequences would likely be considerably lower than those estimated for the shipment of dry concentrate.

4.5.1.3 Chemical Shipments

Truck shipments of process chemicals, including small quantities of analytical reagents, to the Crownpoint facility and the satellite plants could result in local environmental impacts if the trucks are involved in an accident. Processing chemicals required at the project sites are exhibited in Table 4-12. All uranium recovery sites, including mills and solution mines, require similar processing chemicals. The potential for shipping accidents is similar at all sites as well.

Table 4-12. 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 ($NaHCO_3$)	Hydrogen peroxide (H_2O_2)
Sodium carbonate (Na_2CO_3)	Carbon dioxide (CO_2)
Sodium hydroxide (NaOH)	Oxygen (O_2)
	Diesel oil
	Bottled gasses
	Liquified petroleum gas (LPG)

4.5.2 Alternative 2 (modified action)

Several alternative sites could be selected for yellowcake drying and packaging. Use of either the Church Rock or the Unit 1 facilities would not appreciably change the potential impacts discussed for transporting processed yellowcake from the Crownpoint facility. The use of the Ambrosia Lake facility near Milan, New Mexico, would slightly increase the risk associated with transporting uranium slurry, which is small compared to that for yellowcake, and slightly decrease the risk of transporting yellowcake since Milan is about 50 miles closer to the yellowcake conversion plant in Illinois. The use of HRI's Kingsville, Texas, facility would significantly increase the risk of transporting uranium slurry and slightly increase the risk of transporting yellowcake.

4.5.3 Alternative 3 (no action)

There would be no transportation risk associated with the no action alternative.

4.6 HEALTH PHYSICS AND RADIOLOGICAL IMPACTS

This section describes an analysis of estimated incremental radiological impacts to the environment and the population that would be contributed from the proposed project. The primary radiological impact to the environment in the vicinity of the project results from naturally occurring cosmic and terrestrial radiation and naturally occurring radon-222 and its daughters. The average whole-body dose rate to the population in this part of New Mexico includes a dose of 1.5 mSv/yr (150 mrem/yr) from local natural background radiation and 0.75 mSv/yr (75 mrem/yr) from medical procedures, based on national average. Therefore, total background is estimated to be about 2.25 mSv/yr (225 mrem/yr). Dose estimates and airborne concentrations of radionuclides from the proposed project do not include natural background and are incremental values.

This analysis examines three types of potential exposures to members of the public. During project operations, releases could occur in the form of air releases of particulate and gases. Additionally, HRI would have to dispose of waste materials from the ISL process. After operations, HRI would have to reclaim well fields and facility grounds to allow unrestricted release in the future.

4.6.1 Alternative 1 (the proposed action)

Analysis of potential air releases is primarily based on estimated releases of radioactive materials, determined by HRI, using an NRC radiological dose assessment code known as MILDOS-Area (ANL 1989). HRI ran separate MILDOS-Area simulations for operations in the Crownpoint and Church Rock areas. The Crownpoint area includes operations at both Unit 1 and Crownpoint facilities. The operations at each of the facilities are somewhat similar except that final drying and packaging of uranium-238 would take place only at the Crownpoint facility. Detailed analyses of the estimated radiological impacts of the proposed operations to nearby individuals and the entire population within 80 km of each facility have been performed.

With HRI's proposed action, there would be no radioactive waste material released into surface waters. Although some contaminated water leaked from retention ponds could affect the groundwater system, no significant contribution to dose by water pathways is anticipated. As a control, HRI would be required to perform environmental monitoring to provide early detection of any seepage from retention ponds that might occur and to take appropriate mitigating measures. Solid and sludge waste material would be sent to a licensed disposal site for burial. Waste water would be disposed of primarily in evaporation ponds after the volume has been reduced by either reverse osmosis or brine concentration. During restoration, land application may be used, due to the much higher volume of waste water created.

Radiological effects during project construction would include natural background plus remnant radiation stemming from previous mining and milling activities near the Church Rock site. As each well in the mine units is drilled through the Westwater Canyon sandstone, drill cuttings containing uranium ore would be entrained into the drilling mud. The relative volume of uranium in the drilling mud would be minute, and there would be no significant radiological impact to the area. Ore cuttings would be entrained in the wet drilling mud, and would be contained in the mud pits. HRI would allow the pits to dry for a time, and then backfill them with clean soil when the drilling site is reclaimed. In addition, HRI would be required to verify that well fields have been properly reclaimed and meet appropriate requirements before releasing the well field back to unrestricted use.

4.6.1.1 Crownpoint and Unit 1

Air Releases

Source Term. Operations in the immediate vicinity of the town of Crownpoint would occur at both the Crownpoint and Unit 1 sites, each of which would be brought into production on different schedules. Table 4-13 shows the planned schedule of operations at the two facilities. Analysis of radiological effluents was done for the fourth time step, in which the operations are at a maximum at both sites.

Table 4-13. Crownpoint and Unit 1 timeline

Year	Actions
1998–1999	Unit 1—Production flow only Crownpoint—Drying only
2000–2001	Unit 1—Production flow and limited restoration Crownpoint—Production flow only
2002–2014	Full production flow and restoration flow
2015–2018	Restoration flow only

HRI has determined that the project would have controlled releases from three areas (source terms) within each operation. The source terms are: (1) the resin transfer/process circuit; (2) the process circuit pressure vents; and (3) land application releases. Typical ISL uranium mines have additional source terms, but HRI has proposed various modifications to its operations to remove radon source term locations. Engineering modifications were made to the production and restoration bleed stream to eliminate radon dispersion into the environment from waste water. In both situations, process bleed and restoration stream waters would be circulated through vented tanks. The off-gas would be captured, compressed, and injected into the lixiviant injection system for reintroduction into the ore zone. The off-gas from the bleed streams would largely consist of carbon dioxide, but would also contain virtually all radon gas dissolved in the lixiviant when it is pumped to the surface.

The release from the resin transfer/process circuit assumes that each IX column would contain 1.323 m^3 (3500 gallons) of process water and would be vented three times a day. This value is conservative because each column would actually contain a large volume of resin, and less water. It is further assumed that the water contains a dissolved radon concentration of 4.9 MBq/m^3 (133,000 pCi/l) with a very conservative 100 percent radon evolution rate. This results in a calculated radon release of 68 GBq (1.83 Ci) per year.

The process circuit pressure vents situated on trunk lines would discharge for 2 seconds every 5 minutes. With a carrying capacity of 0.25 m^3/s (4000 gpm) for each trunk line and 20 total vents, the radon released by this system would be approximately 110 GBq/yr (2.96 Ci/yr). This value is conservative because it assumes that all trunk lines are functioning continuously at the maximum proposed flow rate.

Restoration water would not be open to venting until it arrives at the land application area in Section 12. The source term for modeling was based on equal volumes of water from each of the facilities being

disposed at the land application area. All of the releases are assumed to happen in the center of Section 12. Based on a dissolved radon concentration of 4.9 MBq/m^3 (133,000 pCi/l) and a flow rate of 0.019 m^3/s (300 gpm), the source term from each facility would be 2.9 TBq (79.35 Ci), or a total of 5.8 TBq (159 Ci), per year. It assumes 100 percent evolution of radon-222 and a high flow rate for restoration water.

Traditionally, open hearth dryers at uranium recovery facilities are a primary source of airborne particulates. The vacuum dryer proposed by HRI is a state-of-the-art, zero-release unit that would result in very minimal particulate emissions from the drying and packaging areas. The proposed drying system would have no vent stack. Additionally, because the ISL production circuit is a wet process, no routine radiological particulate emissions source terms are predicted from other portions of the process circuit. The vacuum dryer is more fully described in Section 2.1.2.1. HRI performed a separate MILDOS-Area calculation of emissions from the drying and packaging areas (HRI 1994). The modeled source term for the dryer at the main process facility was based on data gathered for U-238 at an ISL facility using a similar vacuum dryer in Texas. Using an assumption that the measured value of the lixiviant ratio between Ra-226 and U-238 was constant, the source terms resulted in the following values: U-238, 9.0 kBq/yr (0.243 μCi/yr); Th-230, Ra-226, Pb-210, each 58 Bq/yr (1.56 nCi/yr).

Population Distribution. Population census data for 1980, updated to 1990 by projections and field verified, were used in the MILDOS-Area program. Population data for input into the program were determined for persons living within 5 km and 80 km (3 and 50 mi) of the Crownpoint site. HRI determined that approximately 3,600 persons live within 5 km of the Crownpoint process building, and that 76,000 persons live within the 80 km radius. Residences found within lease areas, the nearest residence downwind, and total populations were used in each modeling run to determine compliance with regulatory dose restrictions.

Meteorological Parameters. Weather data used in the MILDOS-Area simulations were obtained from U.S. Department of Commerce records maintained for Gallup, New Mexico. Gallup is located about 16 km (10 mi) southwest of the Church Rock site, and 56 km (35 mi) from Crownpoint. Gallup is the nearest active weather station maintaining the complete weather information necessary to run the MILDOS program. More information on meteorology can be found in Section 3.1.1.

Individual Receptor Locations. HRI modeled 38 separate receptors for the Crownpoint operational area. The Crownpoint receptors are actual residences or multi-use locations (e.g., churches) near the main processing facility or in the Unit 1 lease area (Figure 4-3). These receptors include nearest residences, nearest downwind residences, population concentrations, and hypothetical facility and well field boundary receptors. HRI would be required to implement a comprehensive environmental monitoring program to determine the annual doses to individuals in unrestricted areas.

Exposure Pathways. Potential environmental exposure pathways by which persons could be exposed to radioactive air effluents are presented schematically in Figure 4-4. Estimated dose commitments to humans are based on the proposed facility design and actual characteristics of the site environment. NRC's analysis considers both radioactive particulates and gaseous releases to the atmosphere.

Environmental exposure pathways of concern for airborne effluents from the project include inhaling radioactive materials in the air, particularly radon and its daughters. To a much lesser degree, external

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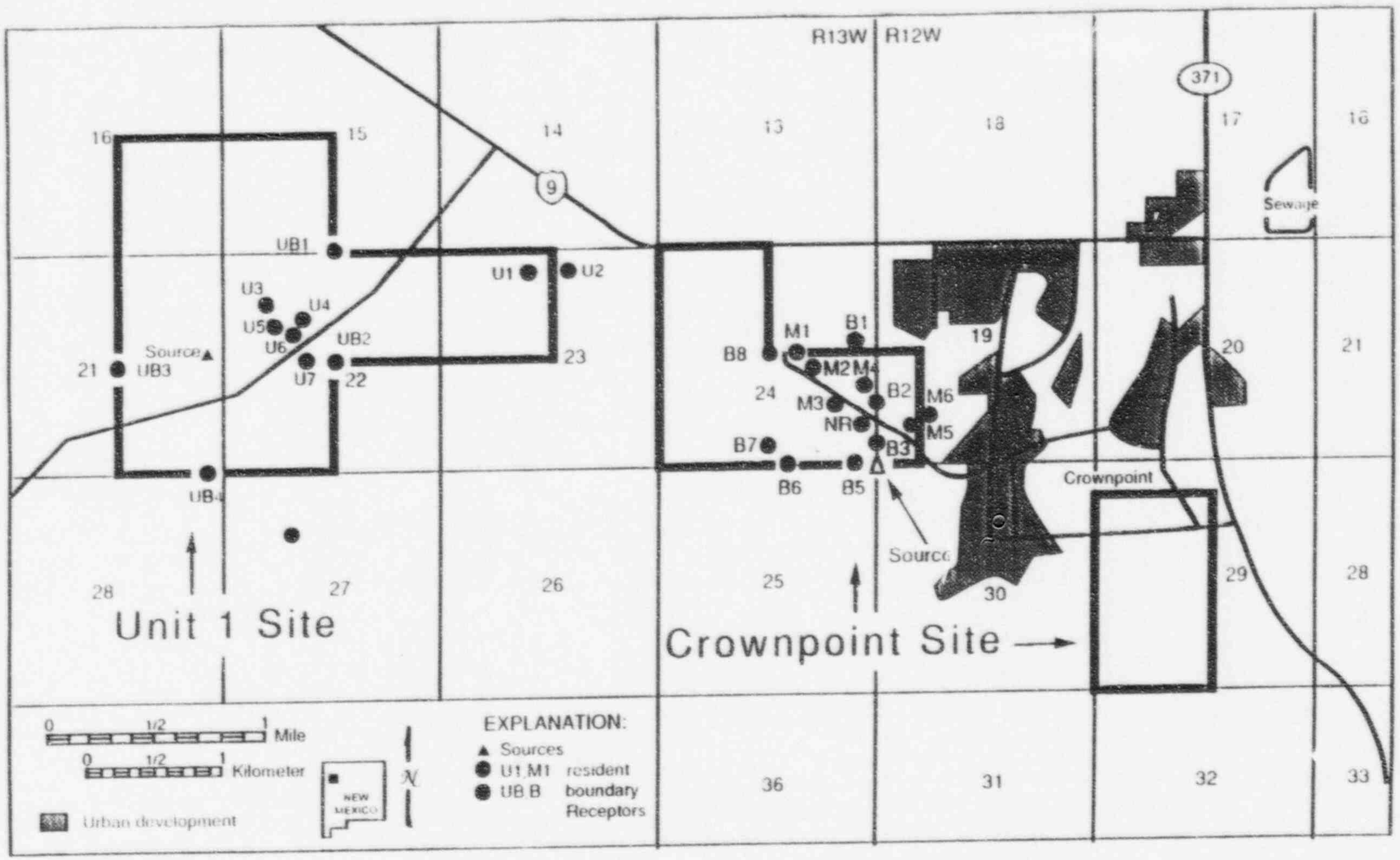

Figure 4-3. Residences and boundary receptors in the Crownpoint and Unit 1 areas.

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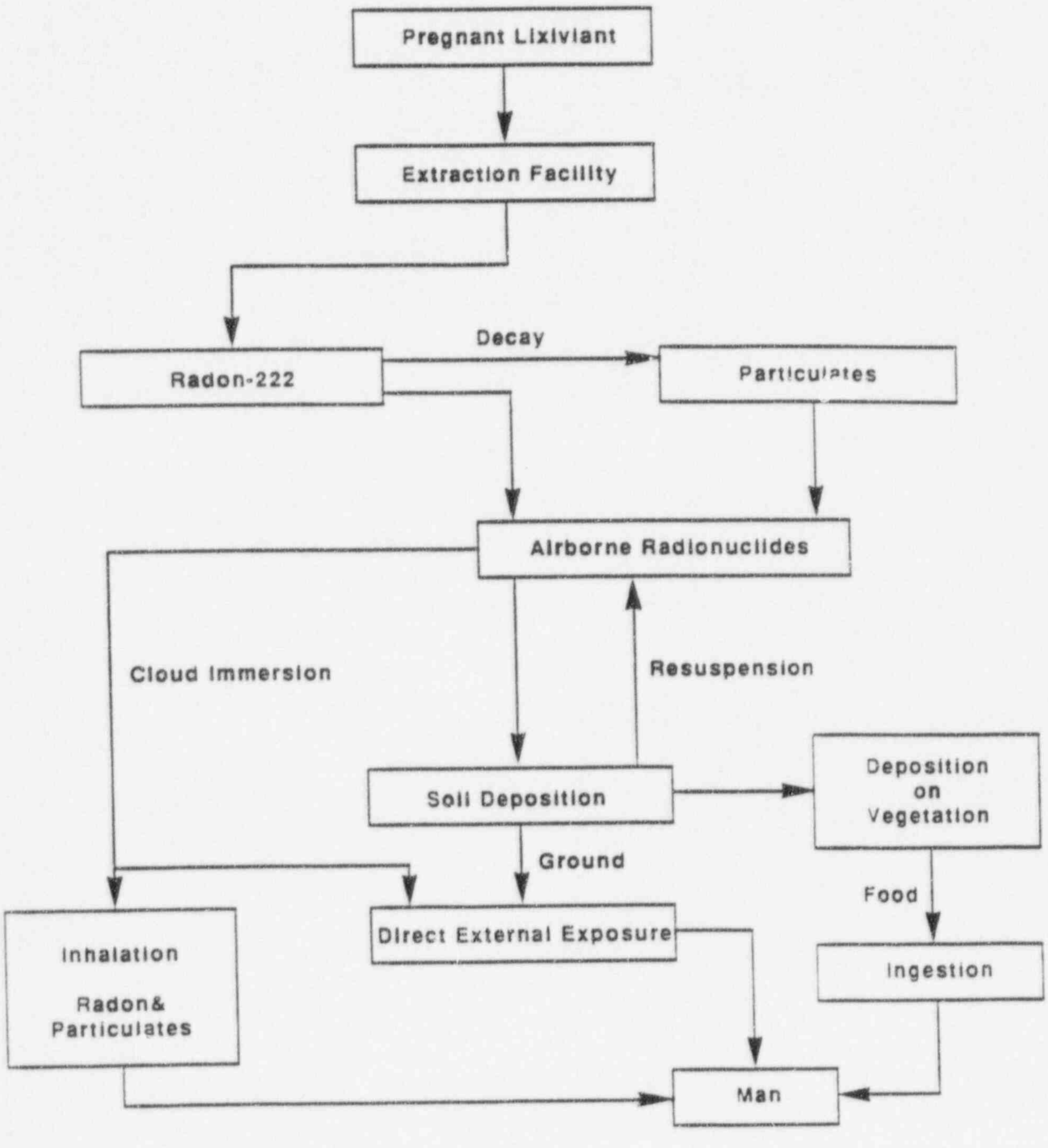

Figure 4-4. Potential exposure pathways for Radon-222 and its daughters, escaping the uranium recovery process and waste water treatment facilities.

exposure would occur from radioactive materials in the air or deposited on ground surfaces, and possibly ingesting contaminated food products (vegetables, milk, and meat) raised locally.

Regulatory Limits on Exposure for Individuals. Permissible dosage limits found in 10 CFR Part 20 for individual members of the public are 1 mSv (100 mrem) total effective dose equivalent (TEDE), and 0.02 mSv/hr (2 mrem/hr) from any external sources. Compliance with the annual dose limit to the public (10 CFR §20.1301) can be shown by calculating the dose to the individual at greatest risk (nearest residence) or compliance with annual concentration levels (10 CFR Part 20, Appendix B) at the site boundary. Two EPA standards apply to this operation. EPA's established average annual dose limits, found in 40 CFR 190, *Environmental Radiation Protection Standards for Nuclear Power Operations*, are 0.25 mSv (25 mrem) whole body, 0.75 mSv (75 mrem) to the thyroid, and 0.25 mSv (25 mrem) to any other organ for a member of the public. The other EPA standard, found in (currently suspended) 40 CFR 61, Subpart I, *National Emissions Standard for Hazardous Air Pollutants*, is a 0.1 mSv (10 mrem) TEDE limit. The EPA standards exclude radon and its daughters.

Estimated Doses at Modeled Receptors. The dose assessment presented here considers doses to infants, which are slightly more sensitive than other age categories. All modeled total annual dose commitments predicted at nearest residences are below the TEDE limits found in NRC regulations. Releases from the Unit 1 site consist only of radon and, thus, are excluded from the evaluation of 40 CFR 61, Subpart I and 40 CFR 190. Particulate releases from the main processing facility at Crownpoint would be minimal and well below the EPA standards. The estimated dose commitments during periods of simultaneous operations at both Crownpoint and Unit 1 with maximum releases are shown in Table 4-14. The dose estimates include dose commitment due to radon and its daughters.

Airborne Concentrations of Radionuclides. In addition to the dose estimates, the MILDOS-Area code presents the estimated airborne concentration of radionuclides at the various residential and boundary receptor locations near the processing sites. The MILDOS-Area code was run for both the combined radon sources at the two facilities and a separate calculation for the minimal particulates released from drying and packaging areas. A table of the calculated radon-related concentrations, for the same receptor locations as shown in Table 4-14, is shown in Table 4-15 for Crownpoint and Unit 1.

At Crownpoint, the nearest residence is found adjacent to the plant site, less than 1 km away. Projected concentrations of airborne radionuclides there were modeled assuming no emission controls for radon. The resulting values are small percentages of the allowable effluent limits for unrestricted areas (Table 4-15, receptor NR). Predicted radon-222 values are 1.5 percent of the maximum limit. Each radon daughter modeled was several orders of magnitude less than the allowable limits. For other nearby residences, the projected concentrations of airborne radionuclides were similar or lower than the nearest residence, and therefore, well below the maximum allowable concentrations for unrestricted areas.

Evaluation of Radiological Impacts on the Public. Calculated annual individual dose commitments are only small fractions of the NRC limits for radiation exposure in unrestricted areas, as specified in 10 CFR Part 20, *Standards for Protection Against Radiation*. Calculated dose commitments to actual receptor locations are also well below limits specified in EPA's standards (40 CFR Part 190 and 40 CFR 61, Subpart I). Verification that these regulatory criteria are not exceeded would be provided by the required environmental monitoring program.

Table 4-14. Estimated TEDE doses from air effluent releases from the Crownpoint Project facilities to various receptor locations

Crownpoint		Unit 1		Church Rock	
Receptor	TEDE[a]	Receptor	TEDE	Receptor	TEDE
MX1	0.21	U1RX1	0.29	CRR 1	0.017
MX2	0.27	U1RX2	0.29	CRR 2	0.019
MX3	0.35	U1RX3	0.27	CRR 3	0.024
MX4	0.46	U1RX4	0.27	CRR 4[b]	0.25
MX5	0.28	U1RX5[b]	0.28	CRR 5	0.055
MX6	0.23	U1RX6	0.28	CRR 6	0.033
MX7	0.14	U1RX7	0.26	CRR 7	0.017
NR	0.76			CRR 8	0.011
School	0.07			CRR 9	0.012

[a]In mrem/yr; for mSv/yr, divide by 100.
[b]Nearest residence.

Liquid Waste Disposal

HRI has proposed two possible ultimate waste disposal techniques for waste waters remaining after volume reduction has been completed: evaporation ponds and land application. The use of evaporation ponds would result in minimal offsite releases under normal operations due to the pressurized system removing the radon from the circuit. Land application could result in exposures to individuals in the far future, and the impacts need to be evaluated.

The land application option would only be used for mine waste water resulting from restoration activities at each of the facilities. Each facility would have a separate irrigation plot of 21 ha (52 acres) on Section 12. Air releases of radon during irrigation were analyzed using MILDOS-AREA with the source term as described above. The potential impacts to a future resident of Section 12 for ground contamination are assessed using the RESRAD code (ANL 1995), which was developed by the U.S. Department of Energy to calculate the risks from residual amounts of radioactivity in the environment.

The treated waste water would have average constituent values of 37 Bq/m^3 (1 pCi/l) and 1 mg/l for radium and uranium, respectively. HRI estimates that restoration would take four pore volumes. Based on this volume flow and the individual irrigation plot area of 21 ha (52 acres), the estimated maximum radionuclide concentrations are shown in Table 4-16. Since the expected accumulation would be sensitive to the amount of water needed for restoration, if the number of pore volumes needed increased radionuclide concentrations (and calculated doses) would increase similarly, unless HRI used larger irrigation plots to

Table 4-15. Airborne concentrations of radon and daughters at selected receptor locations near the Crownpoint and Unit 1 facilities

Location	Rn-222 (WL)[a]	Pb-210[b]	Bi-210[b]	Po-210[b]
		Crownpoint		
MX1	1.55E-05	2.3E-18	5.4E-21	3.4E-25
MX2	1.55E-05	2.3E-18	5.5E-21	3.6E-25
MX3	1.55E-05	2.3E-18	6.1E-21	4.4E-25
MX4	1.5E-05	2.2E-18	6.0E-21	4.4E-25
MX5	1.3E-05	2.1E-18	5.9E-21	4.6E-25
MX6	1.2E-05	2.0E-18	5.7E-21	4.5E-25
MX7	9.8E-06	1.7E-18	4.8E-21	3.8E-25
NR[c]	1.6E-05	2.3E-18	6.4E-21	4.9E-25
School	5.8E-06	1.5E-18	4.9E-21	4.7E-25
		Unit 1		
U1RX1	2.5E-05	3.8E-15	8.0E-21	4.6E-25
U1RX2	2.4E-05	3.5E-18	7.0E-21	3.9E-25
U1RX3	2.3E-05	6.6E-18	2.3E-20	2.1E-24
U1RX4	2.3E-05	6.6E-18	2.2E-20	2.0E-24
U1RX5[c]	2.3E-05	6.6E-18	2.2E-20	2.0E-24
U1RX6	2.4E-05	6.5E-18	2.2E-20	2.0E-24
U1RX7	2.4E-05	6.8E-18	2.3E-20	2.1E-24
Limits[d]	1.1E-3	4E-12	2E-10	7E-12

[a]Units of working levels, which accounts for levels of short half-lived daughter products.

[b]Units of fCi/ml; for pCi/m^3, multiply by 10^{12}; for Bq/m^3, multiply by 3.7×10^{10}.

[c]Nearest residence downwind, assuming Gallup wind rose.

[d]Concentration limits in 10 CFR Part 20, Appendix B. Continuous exposure to concentrations at the limit will result in approximately 0.5 mSv (50 mrem) per year.

counter the increased volume of water. HRI has additional acreage available in Sections 12 and 17 for irrigation area.

Radon was assumed to be released from the restoration water immediately prior to land application at the center of Section 12 for both restoration flows. Receptor locations at the edges of Section 12 were analyzed, resulting in the estimated doses in Table 4-17.

Table 4-16. Estimated accumulation in land application soils

Parameter	Unit 1	Crownpoint	Church Rock
Ra-226 (pCi/g)	0.068	0.081	0.061
Uranium (ppm)	16.7	20.0	15.2

Table 4-17. Estimated doses at the boundary of Section 12 due to land application of restoration fluids

Location	TEDE (mrem/yr)
East (IBR 1)	0.31
North (IBR 2)	0.42
West (IBR 3)	0.28
South (IBR 4)	0.21

To calculate potential future exposure, the following conservative scenario is assumed. Immediately after cessation of operations, it is assumed that an individual or family moves onto the irrigation plot, unaware of the residual radioactivity present. The individual, who is termed an inadvertent intruder, proceeds to spend 55 percent of the time indoors on site, 21 percent outdoors on site (5 hours per day for 365 days) and 24 percent of the time away from the site. A garden grown in the contaminated area is assumed to supply 50 percent of the resident's vegetable, grain, and fruit diet. The resident maintains a small group of cattle, which supply all of the resident's milk and 50 percent of the meat diet. Because of the conditions in the area, water for drinking is assumed to come from offsite. Additionally, no aquatic food sources are assumed to be contaminated.

An assessment is calculated for each section. For the intruder into Section 12, the ground concentrations for the entire 104 acres of land application area is conservatively assumed equal to the higher concentrations estimated for the main facility. The highest exposures could occur immediately after closure, and the maximum calculated doses are shown in Table 4-18. The highest dose occurs in Section 12, which not only would have higher concentrations of radionuclides, but a larger area of residual radioactivity. The calculated doses are within acceptable levels for waste disposal techniques and potential exposures in unrestricted areas.

The State of New Mexico has the regulatory authority to grant the land application permit. NRC would be a participant in the permitting process.

Decontamination and Disposal

HRI would be required by license condition to submit a detailed decommissioning plan to NRC one year prior to beginning closure of either the Crownpoint or Unit 1 production facilities. Before release of an area

Table 4-18. Potential doses to residential farmers

Nuclide[a]	Section 12 mSv (mrem)	Section 17 mSv (mrem)
Ra-226	0.09 (9)	0.07 (7)
Uranium	0.025 (2.5)	0.02 (2)
Total	0.115 (11.5)	0.09 (9)

[a]Includes all appropriate doses from daughter products.

to unrestricted use (i.e., well field, land application area, production facilities), HRI would be required to provide information to NRC to verify that radionuclide concentrations meet applicable radiation standards. Currently, the soil cleanup criteria for natural uranium not in equilibrium with its daughters is 1.1 Bq/g (30 pCi/g), and for radium is 0.19 Bq/g (5 pCi/g) in the top 15 cm and 0.57 Bq/g (15 pCi/g) for the rest of soils.

4.6.1.2 Church Rock

Air Releases

Project operations at the Church Rock site would be similar in scope and function to those at the Unit 1 site. The proposed time scale of operations is eight years, as shown in Table 4-19. The only radiological air effluents during operations would be radon. To minimize releases, HRI proposes to use a pressurized circuit.

Table 4-19. Church Rock timeline

Year	Actions
1	Production flow with limited restoration
2–3	Production flow only
4–6	Full production and restoration flow
7–8	Restoration flow only

Calculations for all the facilities were conducted on the radon released from two source terms: resin transfer and pressure vents. In the process circuit, consisting of circulating production water through IX columns, the calculated radon release was 66 GBq (1.784 Ci) per year. This value assumes that each IX column would contain 1.323 m^3 (13,230 l) of process water and would be vented three times a day. This value is conservative because ea h column would actually contain a large volume of resin, and less water. It is further assumed that the wat contains a dissolved radon concentration of 4.8 kBq/l (129,610 pCi/l) with a very conservative 95 percent radon evolution value. No particulate source terms exist for the Church Rock facility because the dryer would be located at the Crownpoint main facility.

The process circuit pressure vents situated on trunk lines would discharge for 2 seconds every 5 minutes. With a carrying capacity of 0.25 m^3/s (4000 gpm) for each trunk line and 20 total vents, the radon released by this system would be approximately 110 GBq/yr (2.96 Ci/yr). This value is conservative because it assumes that all trunk lines are functioning continuously at the maximum proposed flow rate.

For the Church Rock site, 575 people live within 5 km and approximately 74,000 persons live within the 80 km radius. Residences found within lease areas, the nearest residence downwind, and total populations were used in each modeling run to determine compliance with regulatory dose restrictions. Seventeen receptors were modeled near the Church Rock facility (Figure 4-5). Other modeling assumptions are similar those made for the Unit 1 and Crownpoint sites. The calculated exposures for the receptor locations are shown in Table 4-14. Calculated airborne concentrations of radon and daughters at the site boundary and nearest downwind residence (based on Gallup wind rose) are shown in Table 4-20.

For the Church Rock analysis, radon emission controls reduce the airborne concentration by approximately a factor of 10 (see Table 4-20). The resulting values at the nearest residence are approximately 0.5 percent and 7.6 percent of the limit, with and without the emissions controls, respectively. The calculated exposures and potential concentrations, with emission controls, are a small fraction of the regulatory limits.

Liquid Waste Disposal

Similar to both the Crownpoint and Unit 1 facilities, the Church Rock facility may use land application to dispose of its restoration waste water. This waste water would be pre-treated to minimize contaminants and volume. The waste water would then be applied to a 52-acre site in Section 17. Additional area in Section 17 is available, if needed.

Expected air concentrations due to land application would be similar to the analysis for the Crownpoint/Unit 1 land application area. As indicated Table 4-16, expected soil concentrations for the Church Rock property are lower than concentrations expected from either Unit 1 or Crownpoint. The resulting peak exposure to the intruder is approximately 0.09 mSv/yr (9 mrem/yr), which would occur in the first year after cessation of irrigation (Table 4-18). The calculated dose is within acceptable levels for waste disposal techniques and potential exposures in unrestricted areas.

Decontamination and Disposal

HRI would be required by license condition to submit a decommissioning plan to NRC one year prior to beginning closure of the Church Rock facility. Before release of an area to unrestricted use (i.e., well field, land application area, production facilities), HRI would be required to provide information to NRC to verify that radionuclide concentrations meet applicable radiation standards. Currently, the soil cleanup criteria for natural uranium not in equilibrium with its daughters is 1.1 Bq/g (30 pCi/g), and for radium is 0.19 Bq/g (5 pCi/g) in the top 15 cm and 0.57 Bq/g (15 pCi/g) for the rest of soils.

4.6.1.3 Regional and Cumulative

Annual doses to the population within 80 km (50 mi) of the Crownpoint Project from air releases are estimated as part of the MILDOS-Area calculations. The total annual population dose was estimated for the period in time of greatest releases from all areas. Two population dose estimates were calculated—one

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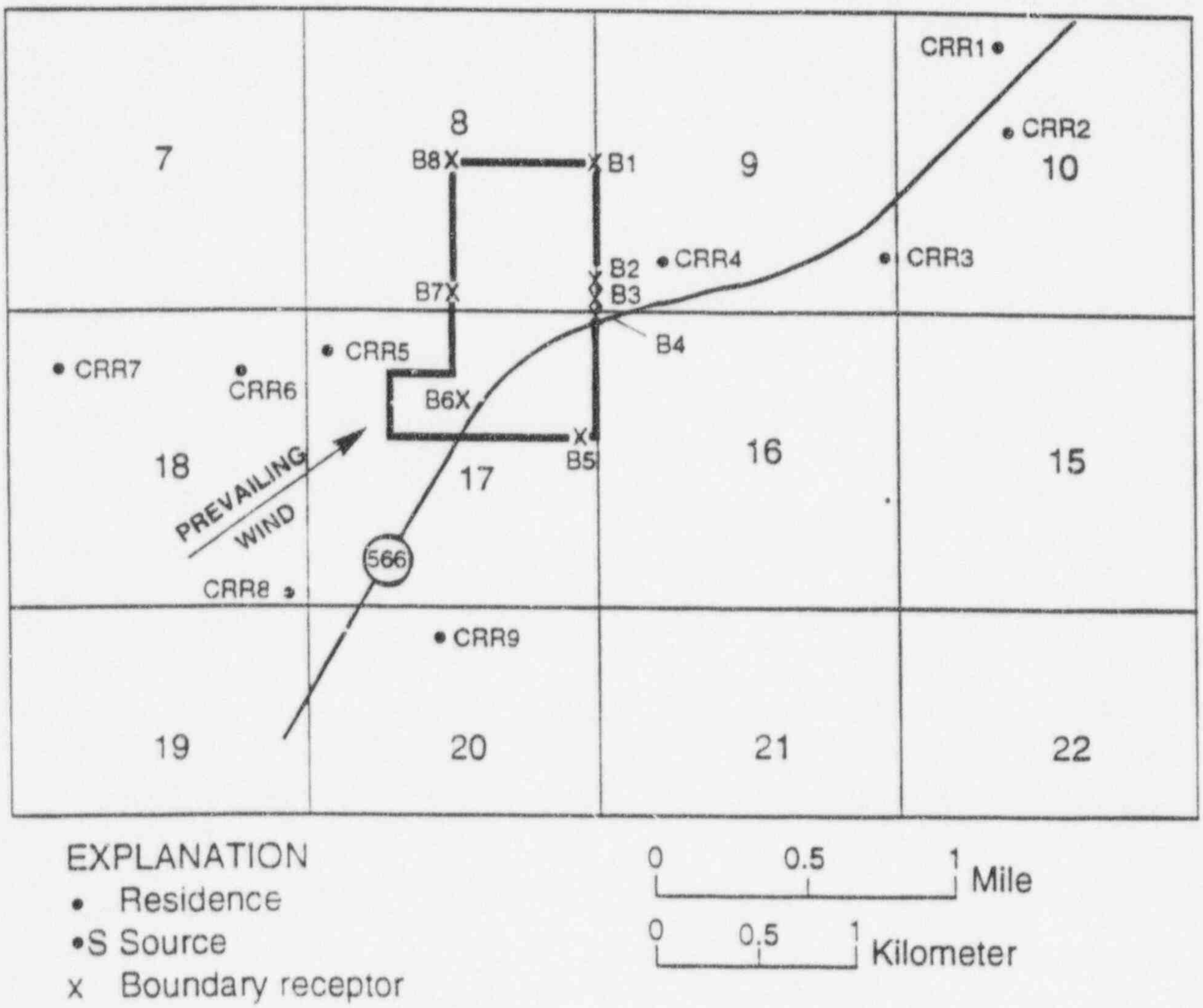

Figure 4-5. Residences and boundary receptors in the Church Rock area.

Table 4-20. Airborne concentrations of radon and daughters at selected receptor locations near the Church Rock satellite facility

Location	Rn-222 (WL)[a]	Pb-210[b]	Bi-210[b]	Po-210[b]
		Totals (pressurized system)		
BR-1 N	3.6E-06	3.3E-20	1.5E-23	1.9E-28
BR-2 NE	1.1E-06	8.5E-21	2.0E-24	1.4E-29
BR-3 E	8.1E-06	6.2E-21	1.4E-24	9.9E-30
BR-4 SE	3.5E-06	4.8E-21	1.1E-24	7.8E-30
BR-5 S	7.3E-07	9.2E-21	4.6E-24	6.7E-29
BR-6 SW	1.8E-06	1.8E-20	8.6E-24	1.2E-28
BR-7	6.7E-06	1.8E-20	5.8E-24	5.8E-29
BR-8 NW	2.2E-06	2.8E-20	1.4E-23	2.1E-28
CRR 4[c]	5.7E-06	2.5E-20	8.8E-24	9.6E-29
		Totals (unpressurized system)		
BR-1 N	5.4E-05	4.3E-19	1.7E-22	2.0E-27
BR-2 NE	3.4E-05	1.8E-20	4.1E-24	2.8E-29
BR-3 E	2.8E-05	1.3E-20	2.9E-24	2.0E-29
BR-4 SE	1.3E-05	1.0E-20	2.3E-24	1.6E-29
BR-5 S	7.3E-06	8.8E-20	4.4E-23	6.3E-28
BR-6 SW	1.4E-05	1.8E-19	8.9E-23	1.3E-27
BR-7 W	4.7E-05	2.6E-19	9.7E-23	1.0E-27
BR-8 NW	2.0E-05	3.2E-19	1.8E-22	2.8E-27
CRR 4	8.4E-05	1.6E-19	4.1E-23	3.3E-28
Limits[d]	1.1E-03	4E-12	2E-10	7E-12

[a]Units of working levels, which accounts for levels of short half-lived daughter products.
[b]Units of fCi/ml; for pCi/m^3, multiply by 10^{12}; for Bq/m^3, multiply by 3.7×10^{10}.
[c]Nearest residence downwind, assuming Gallup wind rose.
[d]Concentration limits in 10 CFR Part 20, Appendix B. Continuous exposure to concentrations at the limit will result in approximately 0.5 mSv/yr (50 mrem/yr).

for the Crownpoint/Unit 1 facilities and one for the Church Rock facility. As the area of impact is similar for both calculations, the results were combined with a total population dose less than 0.01 person-Sv/yr (1 person-rem/yr). The population within the 80 km (50 mi) radius of the entire project is approximately 76,500 persons. Population dose commitments resulting from facility operations represent less than 1 percent of the dose from natural background sources. The population dose from natural background would be approximately 170 person-Sv/yr (17,000 person-rem/yr).

The northwest corner of New Mexico has a long history of uranium mining and milling. Effects of previous mining and milling operations in the area need to be considered, as they relate to the proposed licensing action. The Church Rock facility as proposed would mine the same area as was previously mined by underground techniques which supplied ore to the Church Rock mill site. Uranium mining was a large employer of the area and many individuals worked in the mining and milling operations. Early mines and mills operated under much more relaxed standards than are present today, and this resulted in large exposures to radioactive materials, especially radon and its daughters. The exposures were large enough to result in a high incidence of cancer among workers, and information gathered on these workers resulted in development of risk factors on radon.

Additionally, the methods used to mine and mill the uranium, so called, "conventional" methods, resulted in very large amounts of radioactively and chemically contaminated sands and slimes, also known as tailings. In 1978, the U.S. Congress passed the Uranium Mill Tailing Radiation Control Act, which required standards to be developed to control exposures from tailings and clean up past sites of uranium milling. In 1979, the tailings pond dam at the Church Rock site failed and approximately 3.56×10^5 m^3 (94 million gal) of tailings liquid and 1100 tons of tailings solids were released into the Rio Puerco River (NRC 1981). The area contaminated by the spill was surveyed and cleaned to standards developed by the New Mexico Environmental Improvement Division.

The proposed project would provide a negligible increase to the cumulative impacts in the area due to uranium mining and milling. HRI has proposed an ISL process which by its nature does not result in large amounts of tailings or environmental releases of radioactive particulate material. Additionally, HRI has proposed to use a vacuum dryer, which reduces the total releases of radioactive particulates to nearly zero, and a pressurized process circuit with a feedback system to return radon to the mine zone, which reduces environmental radon releases. The expected exposures from the remaining possible sources of radon are a very small fraction of the allowable limits for exposure of the public. The amount of generated tailings is very small, in the tens of cubic meters per year, and will be disposed of at a off site licensed facility. In addition, the facility and related well fields would be required to be decontaminated and decommissioned to the appropriate State and Federal standards.

4.6.2 Alternative 2 (modified action)

4.6.2.1 Alternative Sites for ISL Mining

Reducing the number of sites would reduce the number of potential sources of radon. Estimated environmental effects of the proposed project are small; removing sources would result in further reduction of the dose to both local and regional populations. The largest reductions would be related to the land application of restoration water. Under the proposed action, most of the radiological exposures are from the land application facilities. Each land application facility constructed and operated would result in effluent

of 2.9 TBq (79.35 Ci) ^{222}Rn per year and 21 hectares (52 acres) of land that would have elevated levels of uranium and radium.

At the Church Rock site, areas of the site have greater concentrations of residual radioactivity present than would be allowed in decommissioning the site. Under the proposed action, these areas would generally be cleaned up as part of the wellfield decontamination. Under the alternative where the Church Rock site is not mined, the residual radioactivity would remain in these areas and would not be necessarily remediated.

4.6.2.2 Alternative Sites for Yellowcake Drying and Packaging

HRI proposes to use a vacuum dryer, which would result in nearly zero releases for the drying and packaging of product, and the resulting environmental impacts of air emissions would be minimal. Therefore, selection of another site would result in a minimal change in the dose received by the population surrounding Crownpoint. However, a very small impact would occur to the population surrounding whichever site is selected.

4.6.2.3 Alternative Liquid Waste Disposal Methods

HRI proposes to use waste water volume reduction techniques, evaporation ponds, and land application to dispose of liquid radioactive wastes. Two other waste disposal techniques could be used: surface water discharge and deep well injection.

To allow surface water discharge, a variance would be required because the expected average uranium concentration is greater than the allowable concentration average in 10 CFR Part 20, Appendix B. Exposures to individuals who drink the water prior to full mixing in the stream could result in an individual dose in excess of the 1 mSv (100 mrem) limit.

Disposa' wastes by deep well injection would reduce exposures to the public from waste disposal techniqu o nearly zero. The requirements and concepts behind deep well disposal would result in no credible scenario in which members of the public could contact the waste, especially at initial concentrations. HRI has indicated they may consider deep well disposal for the Crownpoint Project. To be allowed to conduct deep well disposal, HRI would be required to submit information to NRC, as per 10 CFR 20.2002, detailing the operations and hazards of the proposed deep well.

4.6.3 No Action

If no action is taken, no radiological exposures are estimated to the general public other than natural background, medical-related exposures, and exposures from existing residual contamination. At the Church Rock site, areas of the site have greater concentrations of residual radioactivity present than would be allowed in decommissioning the site. With the proposed project, these areas would generally be cleaned up as part of the wellfield decontamination. Under the no action alternative, the residual radioactivity would remain in these areas and would not be necessarily remediated.

4.7 ECOLOGY

4.7.1 Alternative 1 (the proposed action)

4.7.1.1 Crownpoint, Unit 1, and Church Rock

Construction and operation of the proposed project would damage and destroy flora and fauna in limited areas at each of the three sites. Most of the impacts would occur during initial facility construction, particularly at well and building sites. However, the proposed project is not likely to adversely affect sensitive plant or animal species because no federally- or state-listed or proposed endangered or threatened species or proposed or designated critical habitats occur on project lands (Section 3.5.1.4). Similarly, the absence of permanent surface water on the project sites limits impacts to aquatic resources (Section 3.5.1.3). In contrast, the ecological effects of underground mining and the associated uranium ore milling are, in general, considerably greater (FWS 1980).

Construction

Most impacts on ecological resources would result from land disturbance during well field construction. Construction of HRI's proposed project would include vegetation removal during clearing for facilities (e.g., individual well sites, metering and processing buildings, roads, parking, storage pads, retention or evaporation ponds) and monitoring rings (i.e., monitoring wells surrounding a well field). Approximate land areas of various habitat types that would be disturbed for proposed facilities (excluding evaporation ponds) are listed in Table 4-21. Approximately 40 ha (100 acres) of additional habitat, probably grassland, would be destroyed at each site by clearing and excavation for evaporation ponds.

The total land area disturbed would be about 743 ha (1858 acres), or 73 percent of the approximately 1,022 ha (2,552 acres) comprising the three project sites. After operations are completed, buildings would be removed and disturbed areas would be revegetated with native plants (Section 2.3.3 and Table 2-5). HRI would be required to submit an updated reclamation plan for approval, following review by appropriate state and federal agencies.

HRI proposes to stockpile topsoil removed during construction for subsequent use to reclaim disturbed areas. Stockpiled topsoil and temporarily disturbed areas would be revegetated with appropriate varieties of native plants using the seed mixture given in Table 4-22. This mixture appears acceptable but should be reviewed by the Natural Resources Conservation Services (NRCS) of the U.S. Department of Agriculture for local suitability. Details of preparing for and carrying out seeding and of post-seeding cultural practices, as provided by HRI are acceptable.

Project construction would displace or destroy smaller, less mobile wildlife species on each of the three sites. Small mammals and reptiles would be more subject to mortality from construction than other groups, but impacts would be minor on a regional basis. Many of the affected species, especially small mammals, have high reproductive potential, are common in surrounding habitats, and therefore would be minimally impacted. Larger mammals, birds, and some reptiles would be able to avoid construction areas temporarily and possibly return to remaining suitable habitat after construction is completed. In general, however, it can be assumed that loss of various animal populations would be proportional to the amount of their habitat which is lost (Kroodsma 1985).

Table 4-21. Approximate areas of habitat types to be disturbed by construction at the three project sites

Site	Previously disturbed ha (acres)	Habitat type disturbed in hectares (acres)			Total ha (acres)
		Grassland ha (acres)	Sagebrush-grassland ha (acres)	Juniper/Oak/ Pinyon ha (acres)	
Church Rock					
Facilities	10 (25)	0	27 (66)	0	37 (91)
Well Ring	7 (17)	0	28 (70)	8 (19)	43 (106)
Crownpoint					
Facilities	28 (70)	52 (129)	0	0	80 (199)
Well Ring	10 (25)	52 (129)	0	0	62 (154)
Unit 1					
Facilities	0	187 (462)	0	0	187 (462)
Well Ring	0	116 (287)	0	0	116 (287)
Totals	55 (137)	407 (1007)	55 (136)	8 (19)	525 (1299)

Table 4-22. Seeding mixture proposed for revegetating sites with various soil characteristics

Plant species	Amount pure live seed in pounds/acre (kg/ha)		
	Clay sites	Loamy sites	Sandy sites
Western wheatgrass	6.4 (7.2)	4.8 (5.4)	6.4 (7.2)
Alkali sacaton	0.8 (0.9)	0.7 (0.8)	0.5 (0.6)
Sideoats gramma		2.0 (2.2)	1.8 (2.0)
Indian ricegrass		2.4 (2.7)	
Rocky mountain penstemon			0.3 (0.3)
Little bluestem	0.3 (0.3)	0.6 (0.7)	
Fourwing saltbush	1.2 (1.3)		

The offsite impacts of construction would be small. Construction activities would produce a minor increase in vehicle traffic and, hence, in animals killed on the highway. Construction also would produce a temporary increase in dust, some of which would be deposited on vegetation both on and offsite. However, vegetation in this naturally dusty, arid region is assumed to be adapted to moderate temporary increases of this sort. Excessive dust production would be limited by water application in construction areas, according to stand . regional construction practices.

Operations

Potential impacts associated with routine project operations would be minimal. Large mammal populations would be excluded from the facilities during operations by on—site fencing, but should return to these areas following restoration and reclamation.

No large fresh water bodies occur near the Crownpoint or Church Rock areas; thus, there are no regional sources from which waterfowl might be attracted to waste water retention ponds or to evaporation ponds on a year—round basis. The area is, however, a flyway corridor for migrating waterfowl, although not a high—concentration corridor (Bellrose 1978). Thus, ponds may provide a stopover or resting spot for waterfowl during the spring and fall migration periods. The ponds are not expected to pose significant risk to any migrating waterfowl using them because concentrations of hazardous constituents would be negligible or small. The ponds would store water during the treatment process, and would contain either purified water before it is released (evaporation ponds) or brackish water and briny sludge (process waste water retention ponds).

The degraded waste water in the retention ponds would have elevated concentrations of dissolved solids, potentially elevated levels of trace metals, mildly alkaline pH values, and low concentrations of radionuclides. If the chemical composition of this water is similar to that of the lixiviant (see Table 2-2), the salinity would be in the brackish range (1500–5500 mg/l). This salt concentration would not be high enough to deter some species of waterfowl from using the ponds and might permit growth of salt tolerant aquatic vegetation. If salinities were substantially higher, plant growth would be prevented and waterfowl use would be lessened. In any case, concentrations of potential harmful substances in the waste water retention ponds would not be high enough to harm any birds that might choose to use the ponds as a temporary stopover or resting place during migration.

Birds using the evaporation ponds would not be exposed to hazardous substances because the water would have been treated to remove most impurities. Methods for discouraging waterfowl use would be instituted, if necessary (e.g., limiting bank vegetation that might provide cover, using visual and sound devices to frighten birds, placing wire screens over the water surface, constructing ponds with steep banks).

Disposal of treated water by land application would not be likely to result in harmful accumulations of salts in soil and vegetation because the water would be almost pure. HRI would be required to submit an irrigation plan for approval before implementing such a practice. The plan would address, among other things, application rates, water chemistry, and predicted salt accumulations and their potential impacts.

Well field buildings and trunk pipelines would form intrusions in the habitat of small reptiles and mammals. Pipelines installed on the ground surface would partially block movements by smaller animals. However, some movement would remain possible because each pipeline would be buried where it crosses

local dirt roads. Long continuous surface obstacles would be eliminated by providing either earthen berms over or underpasses below short sections of pipeline at regular intervals.

The offsite impacts of project operation would be minor. Flora and fauna in the areas surrounding the project sites are similar to those onsite and are common in the region. HRI would take steps to minimize erosion and sedimentation both on and off site by (1) not placing wells, roads, or other facilities on steep, currently eroding slopes; (2) vegetating and stabilizing topsoil stored for subsequent use; and (3) constructing drainage diversions where needed to limit flooding potential. Under normal operation, the only routine release would be low concentrations of radon and particulate radionuclides released to the airshed. Provided these concentrations are protective of human health, they would not be expected to adversely affect native plants and animals (Barnthouse 1995).

Accidental spills are not a common occurrence in modern ISL mining operations, but if they occur they would be cleaned up through implementation of a required Spill Response Plan. As a result, spills would be unlikely to extend offsite. Materials likely to be spilled, such as retained waste water, would not contain hazardous constituents in concentrations that would be harmful to wildlife.

4.7.1.2 Regional

Impacts to ecological resources in the region surrounding the project would be minor. There are no unique or high quality habitats in the project sites or surrounding areas, and the animals and plants living there are common throughout the region. Organisms and habitat would decrease in abundance and distribution by only a very small increment. The project sites do not provide quality habitat for and are not frequented by large concentrations of large mammals such as deer, pronghorn, or mountain lions.

Because the impacts of construction and operation at the three sites are expected to be minimal, the project's contribution to cumulative impacts would be limited and primarily associated with land disturbance. After project operations are completed, the lands would be returned to a productive condition.

4.7.2 Alternative 2 (modified action)

4.7.2.1 Crownpoint, Unit 1, and Church Rock

Construction and operation of an ISL project under the modified action alternative would result in ecological impacts similar to, though not identical to, those of the proposed project (Section 4.7.1). The nature and extent of the differences would depend on the alternatives chosen. In general, limiting well field operations to no more than two of the three proposed sites would lessen the probable extent of impacts on biota by limiting the area involved.

Because none of HRI's proposed liquid waste disposal methods (i.e., reinjection, evaporation, and land application) are expected to harm biota significantly, selection of only one or two of these methods also would not result in significant impacts. Nonetheless, selection of only one or two methods would influence the level of potential impacts. In general, reinjection would pose the least risk to wildlife. Evaporation ponds would entail the greatest impacts because of the relatively large land areas required for pond construction.

4.7.2.2 Regional

As with the proposed project (Section 4.7.1.2), impacts to ecological resources in the region surrounding the project would be minor under the modified action alternative.

4.7.3 Alternative 3 (no action)

The no action alternative would result in no change to existing ecological conditions at the three proposed sites or in the region. Land disturbance would be avoided and the area would continue to provide low to moderate quality vegetation communities and wildlife habitat typical of the region.

4.8 LAND USE

4.8.1 Alternative 1 (the proposed action)

Construction and operation of the proposed project would have adverse impacts on existing land uses at the three project sites. Although these impacts would be temporary due to the sequential nature of the proposed mining operations and to HRI's proposals for site restoration and reclamation, some of the impacts could be significant without appropriate mitigation.

The most obvious land use impact would be on-site disturbance and restrictions during project construction and operations. Including previously disturbed areas, approximately 70 percent [255 ha (638 acres)] of the Crownpoint site would be disturbed at some time during the project. If HRI disposes of wastewater from the Crownpoint and Unit 1 sites using off-site land application in Section 12, T17N R13W, an additional 256 ha (640 acres) could be disturbed. Including previously disturbed areas, approximately 70 percent [358 ha (896 acres)] of the Unit 1 site, and approximately 90 percent [130 ha (324 acres)] of the Church Rock site, would be disturbed. If HRI disposes of wastewater from the Church Rock site using off-site land application in Section 16, T16N R16W, an additional 256 ha (640 acres) could be disturbed. However, the impacts of this land disturbance are expected to be temporary and insignificant due to the sequential nature of the project and to HRI's proposals for site restoration and reclamation. During construction, land use in each well field would be restricted in only about 24 ha (60 acres) at a time. Previous licensing experience indicates that well fields can be placed into production approximately 2 ha (5 acres) at a time. Therefore, drilling activities would be concentrated in a small percentage of the proposed sites at any time.

A second, and more significant, land use impact of the proposed project would be the temporary disruption of livestock grazing at project sites. Local residents have expressed concern that this disruption of grazing would adversely affect Navajo who have grazing permits for the land and rely on livestock as an important economic resource. It is true that individuals who currently have grazing permits on project lands would temporarily lose those permits if mining occurs. HRI has secured mineral leases from the individuals or organizations possessing legal titles or having allotments to the resources to be developed. Under the federal General Mining Law of 1872, mineral rights owners can interrupt surface grazing permits in order to remove minerals. Therefore, HRI's leases prohibit livestock grazing during mining operations. To help mitigate the impact of this temporary loss of grazing rights, staff recommends that HRI compensate the permitees directly (for private lands) or indirectly through the relevant tribal (for tribal lands) or federal

agency (BIA for allotee lands). Staff recommends that the Navaho Nation negotiate compensation arrangements for lands where grazing permits are held in tribal trust, and that BIA negotiate compensation arrangements for lands where allotees have grazing permits.

Perhaps the most significant land use impact of the proposed project would be the potential relocation of residents within the Unit 1 site boundaries. Assuming a license is granted for the project, it would not be possible to determine how many individuals or families might have to be relocated until well drilling begins. Field interviews conducted by HRI and NRC in July 1993 indicated that there were seven residences occupied by 26 persons in the Unit 1 lease area. These persons are Navajo allotees (who own the surface and mineral rights) or their tenants. Leases for both the surface use and mineral rights on these allotted lands are administered by the BIA. The BIA and the allotees who would be affected by the proposed project have signed agreements with HRI authorizing mineral leases and surface use of the land for mining activities. In most cases, the individuals and families who would be relocated or denied access to their land were voluntary signatories to the leases negotiated by HRI. The need for relocations and access restrictions, which would be temporary (i.e., for the duration of mining operations in the lease area and until the area has been released for public access), was explained to the signatories as a condition of the leases. However, there may be some instances where individuals or families who are living on allotted lands but who are not signatories to the leases would be required to relocate. Funds to cover such relocations are the responsibility of the allotees who signed the leases, and presumably have been set aside as a condition of the negotiated lease. However, staff recommends that HRI be required by license condition to evaluate potential impacts on and provide direct compensation to any residents of allotted lands who would be required to relocate but who are not signatories to the leases.

4.8.2 Alternative 2 (modified action)

4.8.2.1 Alternative Sites for ISL Mining

The land use impacts of developing alternative combinations of the three project sites would vary. In terms of land disturbance, developing only one or two of the project sites rather than three would decrease impacts proportionately. In terms of the temporary revocation of grazing permits, impacts would be reduced by not developing the Crownpoint and/or Unit 1 sites. The potential impacts of resident relocation could be avoided altogether by not developing the Unit 1 site.

4.8.2.2 Alternative Sites for Yellowcake Drying and Packaging

Changing the location of the yellowcake drying and packaging facilities from Crownpoint to one of the other two sites or to an existing site elsewhere would not result in significant impacts to land use. Adding drying and packaging facilities to HRI's proposed facilities at either the Unit 1 or Church Rock site would mean adding a yellowcake drum storage area, a dryer room, and an office and shower. These minor additions would require a very small increment of land for the expanded plant. Using an existing processing plant elsewhere in New Mexico or in Texas would create no additional land use impacts.

4.8.2.3 Alternative Liquid Waste Disposal Methods

Different combinations of alternative liquid waste disposal methods would have very different land use impacts. Generally, the more land required for a liquid waste disposal method, the greater the potential for

land use impacts. Therefore, the most adverse impacts would likely result from methods that use large evaporation ponds or require more land area for surface discharge or land application.

4.8.3 Alternative 3 (no action)

The no action alternative would result in no land use impacts. There would be no project-related land disturbance, access restrictions, disturbance of grazing rights, or resident relocations at any of the three project sites.

4.9 SOCIOECONOMICS

4.9.1 Employment and Income

Assuming that ISL mining operations at Church Rock would begin in 1997, at Unit 1 in 1999, and at Crownpoint in 2001, Table 4-23 shows projected employment figures. As indicated in Table 4-23, long-term employment with the combined operation of Unit 1 and Crownpoint would be expected to occur starting in about 2003. Operations would continue through 2016 under the initial licensing period.

The employment estimates listed in Table 4-23 reflect only those employees who would work directly for HRI. In addition, HRI would contract for drilling rigs which would include three operating employees per rig and one backhoe operator for every two rigs. The number of rigs required would vary from month to month. A conservative estimate of average contract employment for operating the rigs would be 10 at Church Rock and a combined total of 30 for Unit 1 and Crownpoint. HRI has provided no information on whether the contractor would tend to hire local residents or bring in rig operators from other areas.

Peak HRI employment is expected to be about 180, lasting for two years about four years after Church Rock operations begin in 2001–2002. However, long-term HRI employment would be about 120 starting in 2003. There could be an additional 30 contractor employees for drill-rig operation. These projections are subject to uncertainty because employment and income from the proposed project would depend on the market price for yellowcake and the unit cost of the mining operation. A high market price and low per unit production costs would tend to result in a project of greater production and longer duration. Therefore, local employment and income resulting from the project could be subject to significant variation over time.

HRI estimates that about 10 to 15 workers would be brought in to the Crownpoint/Church Rock area from outside (Pelizza 1996). The licensing period for mining would be through 2016. As mentioned above, the long-term effect on the local economy would include wages for about 150 persons. HRI has made a commitment to hire from the local Navajo community as much as possible. Local hiring preferences are also written into royalty agreements with owners of allotment land at the Unit 1 site. The first hiring priority for these agreements is for the lessor and members of the lessor's immediate family, followed by a general preference for hiring members of the Navajo Nation. The following analysis assumes that beyond the hiring commitment in these lease agreements, HRI would fulfill its Navajo hiring commitment from members of the local communities within the Church Rock and Crownpoint chapters. The focus of this analysis is mostly on potential effects within the Crownpoint Chapter because mining operations there (Unit 1 and Crownpoint) would occur from 2001 to 2016, while operations at Church Rock would occur from 1997 through 2003.

Table 4-23. Summary of projected annual project and community employment, earnings, and royalty income

Site and period of operations	Annual project employment	Annual community employment	Annual project earnings[a]	Annual community employment earnings[b]	Annual community royalty income[c]
Church Rock (1997–2003)	61	44	$1,708,000	$1,056,000	
Unit 1 (1999–2016)	57	38	$1,596,000	$912,000	$1,099,000
Crownpoint (2001–2016)	66	47	$1,848,000	$1,128,000	
Peak employment (2001–2003)	214	144	$5,992,000	$3,456,000	
Long-term employment (includes drill-rig operators) (2003–2015)	153	100	$4,284,000	$2,400,000	$1,552,000

[a]Project earnings include all earnings for all employees that work on the project in McKinley County.

[b]Community earnings are estimated for skills and expertise that are consistent with HRI's contractual and stated intention for preferential hiring of qualified Navajo. Although they could potentially reside anywhere within driving distance, staff expects most Navajo workers to reside within the Crownpoint and Church Rock chapters.

[c]Assumes annual production of 1 million pounds yellowcake at Unit 1 at $15.70 per pound.

Source: Project employment based on projections by HRI; community employment based on staff's assessment of job titles for which area Navajo residents would be qualified and available.

Employment of 150 persons would represent only about 0.5 percent of total existing employment in McKinley County. However, if Navajo hirees are selected from within the Crownpoint area, the employment would be a significant benefit for the Crownpoint Navajo Chapter. Based on a review of job descriptions, at least 85 of the 150 HRI long-term jobs could go to local residents. An additional 15 jobs for drill-rig operations would result in approximately 100 potential jobs for local residents. This would represent about 11.9 percent of the estimated Crownpoint Chapter labor force. The Native American unemployment rate in McKinley County in 1990 was 15.5 percent.

Predicting the effect on community employment of HRI's commitment to Navajo hiring preferences is uncertain. Some jobs would probably go to Navajo living outside the Crownpoint Chapter, and some jobs may go to Crownpoint residents that are now employed outside of the Crownpoint Chapter. Therefore, Crownpoint Chapter unemployment might not be reduced on a one-to-one basis with respect to potential project employment. However, if HRI's employment effort is successful in hiring employees from the Crownpoint Chapter, potential benefits to the local community would have a very significant positive effect.

Projected Navajo employment during operations at the Church Rock site is 44 (Table 4-23). Based on the Church Rock Chapter's 1993 estimated population and the 1990 Navajo average labor force participation rate for McKinley County, this would represent about 6.1 percent of the Church Rock Navajo labor force. If this employment went to persons in the Church Rock community it could result in a significant reduction in unemployment. Potential earnings from the Church Rock site would be about 12 percent of estimated

Navajo earnings in the Church Rock Chapter. Some of the employment for the Church Rock site could go to Navajo from the Crownpoint Chapter because of the advantage in retaining experienced employees for operations at Unit 1 and Crownpoint. Conversely, any employees hired from the Church Rock community could continue employment for operations at Unit 1 and Crownpoint. It should be noted that operations at Church Rock are projected to last for only about 6 years, compared to 17 years at Unit 1 and 15 years at Crownpoint.

Estimated long-term earnings from the proposed project would represent an insignificant percentage of McKinley County income (approximately 0.9 percent). However, as indicated in Table 4-24, it could be a significant percentage of earnings within the local community. In addition to earnings from employment, allotment owners that have royalty agreements could make significant incomes depending on the production and price of yellowcake. Although significant in terms of local community earnings, royalty income would tend to benefit a very small part of the community because it would be concentrated on about nine allotees who own the property leased to HRI.

There would also be purchases associated with the proposed project. For example, major project purchases would include electricity and chemicals. However, the local community would receive only minor benefits from these purchases because it does not supply the types of inputs that would be purchased. The proposed project would require some local overnight accommodations for personnel making site visits. At present, there are no hotel or motel accommodations in the Crownpoint area. This would be an opportunity for developing and operating accommodations in the Crownpoint area and could result in employment for Crownpoint residents.

There would be additional expenditures induced by project earnings. Those employed by the project would make purchases at businesses within the local community, resulting in a benefit to local businesses. For example, the local supermarket could receive a significant benefit from an increase in expenditures. Such increases in local expenditures could result in some additional local employment, although this would probably be on the order of only one or two additional jobs. Much of the additional expenditure resulting from project earnings would result in purchases in larger towns such as Gallup and Grants. Within McKinley County, the additional expenditures would add several jobs; however, the resulting increase in employment and income would not be noticeable at the county level because it would be a very small fraction of total employment and income in McKinley County.

To help mitigate any adverse socioeconomic effects of the proposed project on the local communities, staff recommends that HRI's preference for hiring local Navajo be made explicit in a written plan that would serve as the basis for project hiring. The plan would provide the basis for hiring qualified Navajo who are members of the following Navajo Chapters in the project area: Crownpoint, Church Rock, Nahodishgish, Standing Rock, Mariano Lake, and Pine Dale. The plan should be developed with input and review by local officials such as the Chapter Presidents. The plan should explicitly state how members of the Chapters would be informed about employment opportunities. This plan would help insure that HRI provides and disseminates adequate information to maximize employment opportunities for members of the local communities.

Also, staff recommends that HRI provide an annual report stating how many project employees are Navajo, how many are non-Navajo, and the number Navajo employed from each Chapter. This report should be submitted to the six chapters listed above and to the NRC. The intent of the employment plan and the

Table 4-24. Potential employment and income effects on the Crownpoint Chapter

Average project earnings for all workers	$28,000
Average project earnings for existing residents	$24,000
Project employment as a percentage of estimated total Crownpoint Chapter employment	11.9%
Estimated annual long-term earnings from project for local community members	$2,400,000
Project income as a percentage of estimated total Crownpoint Chapter income	18.3%
Estimated annual royalty income to Crownpoint Chapter Residents (allotees for Unit 1 properties; based on Unit 1 recovery of 1 million lbs. per year at $20 per lb).	$1,099,000
Estimated annual royalty income to Crownpoint Chapter Residents as a percentage of total Crownpoint Chapter income	8.4%
Estimated total earnings and royalty income from the project as a percentage of estimated total Crownpoint Chapter income	26.7%

Note: The estimates contained in this table are intended to provide perspective on the potential effects of the proposed project on local employment and income. The estimates are not certain projections of what will actually happen. Many factors could decrease actual project effects, including hiring from outside local communities and reduced operating levels.

Sources: Crownpoint Chapter total employment estimate based on Crownpoint Chapter estimated 1993 population and average labor participation rates for McKinley County's Native American population reported in the 1990 U.S. Census. Crownpoint Chapter total income estimate based on Crownpoint Chapter estimated 1993 population and average Native American per capita income for McKinley County. Potential employment and income assumes that 100 Navajo residents of the Crownpoint Chapter would receive long-term employment.

annual report would be to help monitor whether HRI's policy of hiring local Navajo is successful and to help measure potential employm . benefits to local communities.

4.9.2 Population

HRI estimates that it would be necessary for 10 to 15 employees to relocate from outside into the McKinley County area for the proposed project. Those relocating from outside would likely be managers and professionals. This influx would result in an increase in McKinley County's population of about 25 to 40 assuming an average household size of 2.5 persons per employee. This would represent less than 0.1 percent of McKinley County's 1990 population of 60,686. It is important to note that an influx of this size is far smaller than influxes that have characterized "boom town" effects. Historically, boom towns have resulted from large natural resource developments in isolated and sparsely populated areas. Such developments have resulted in sudden and relatively large changes in area populations. However, given HRI's commitment to hire locally, it is clear that the proposed project would not result in this type of large population changes.

Within McKinley County, project employees could choose to relocate to areas convenient to the project sites. However, several factors suggest that relatively few employees would relocate into the Crownpoint or Church Rock areas. The limited number of employees that would come from outside the area would probably have very limited opportunity or desire to move into Crownpoint because of the limited housing, distance from urban services and amenities, and cultural differences. It is not unusual for Crownpoint residents to work in Gallup, or for Gallup residents to w. k in Crownpoint. For work at any of the project sites, management and professional personnel moving in from outside McKinley County would tend to settle in Gallup, trading the long commute to the Crownpoint area for access to the urban amenities

available in Gallup. For outsiders wishing to avoid the commute from Gallup, the Thoreau community located about 24 miles south of Crownpoint may be a viable alternative.

4.9.3 Housing

The number of in-migrating project employees that would require housing would be very limited (probably 10–15 persons). In general, housing is in chronically short supply in McKinley County. This situation would confront any project employees relocating from outside the area. However, the Crownpoint area is unlikely to experience in-migration because of the limited housing supply and the distance to urban services and amenities. Any significant housing accommodation within the Crownpoint area would have to be arranged through the Navajo Nation. For employees coming in from outside the area or current residents choosing to upgrade their housing, relocation to areas such as Thoreau, Gallup, and Grants could provide the required amount of additional housing although the available selection would be limited.

4.9.4 Infrastructure, Schools, and Public Services

Typically, most of the demand for public infrastructure associated with a proposed project would be related to increases in population, housing demand, and transportation. As discussed above, increases in population and housing demand associated with HRI's proposed project would not be significant relative to the existing situation. Therefore, no significant or detrimental effects on schools, utilities, or other public services are expected to occur as a result of project-related population growth in Crownpoint or other communities in the project vicinity (Van Dyke 1996i).

Mitigation designed to protect the Westwater Canyon aquifer that supplies water to the local community are outlined in Sections 4.3 and 4.12.1. Mitigations includes well replacement and bonding for operating costs that the community would incur because of the drawdown of the water table. Little or no adverse effect would occur to the community because the mitigation guarantees a process to assure that replacement wells are acceptable. No financial impact would result to the community because the costs of these mitigative measures would be borne by HRI.

Because project-related population increases would be very limited, there would be only slight changes in demand for emergency, fire, and police protection. Although the probability of accidents related to the project's operation is very low, the radioactive aspect of the processed material would result in the need for additional standby emergency services that currently are not required or available in the Church Rock and Crownpoint area. It would be necessary to have contingency plans in case such an accident occurred. HRI has provided a detailed contingency plan for uranium transportation accidents. Some additional equipment and training of local hospital personnel would be required to deal with radioactive contamination. HRI has made a written commitment to provide the local hospital with the proper equipment, on-going training for hospital staff, and a separate room equipped for decontamination (Pelizza 1996a). Similarly, HRI has made a written commitment to the Crownpoint Volunteer Fire Department to provide appropriate training and equipment to respond to a slurry truck accident (Pelizza 1996b). HRI has also proposed a memorandum of understanding that outlines respective responsibilities with regard to emergency medical response and training. Staff recommends that HRI's memorandum of understanding be coordinated with the appropriate local officials and included as part of the project license. The memorandum of understanding should also provide for cooperation with Pinedale Fire District Number 19, the Thoreau Fire District, and White Cliffs

Fire District Number 13, which provide coverage for Church Rock and other areas that could be affected by an accident.

Traffic on roads near the three project sites would increase as project employees commute during the work week. Existing traffic on the roads accessing the project sites is very light and the additional traffic associated with the project would not cause congestion or traffic problems. Average Annual Daily Traffic (AADT) for New Mexico 371 was 3,234 in 1994, and was 3,490 for New Mexico 566 from 1990 to 1994. This volume of traffic is consistent with a peak hour Level of Service (LOS) of C, which is characterized by stable traffic flows. Using the methodology in *Highway Capacity Manual* (Transportation Research Board 1985) for evaluating traffic flow on rural 2-lane highways, at peak project employment (assuming the addition of 100 vehicles at rush hour) the additional traffic would not degrade the existing LOS.

4.9.5 Tax Collections and Distributions

4.9.5.1 McKinley County

The proposed project would generate local revenues for McKinley County through ad valorem taxes on the assets of the project, including facilities, equipment, and the production value of the mining operation. For McKinley County, real property, personal property, and improvements are all taxed at the same rate of $30.45 per $1,000 of assessed value (where assessed value is one-third of market value).

Table 4-25 provides estimates of the project's property tax payments to McKinley County for personal and real property. The personal property tax is based on the value of equipment at each of the proposed mining sites. The taxable value for mining operations is 50 percent of the market value of the mined commodity. Table 4-25 acknowledges the uncertainty of annual tax collection estimates by showing various production and price combinations for yellowcake.

The potential tax contribution of the proposed project to McKinley County would be a significant part of local tax revenues. Based on the assumptions in Table 4-25, McKinley County could collect from 1 to 7 percent of its existing property taxes outside Gallup from the project.

Table 4-26 indicates how McKinley County property taxes on the HRI project would be distributed. Most of the tax collections would go to the General County Operating Fund and for public schools.

4.9.5.2 The Navajo Nation

Potential tax collections by the Navajo Nation would be through the Navajo Business Activities Tax (BAT) and the BAT Construction Tax. The Navajo BAT is a 5 percent tax on gross receipts after deductions, including a standard 10 percent deduction for compensation paid to Navajo employees. The BAT Construction Tax is a 3 percent tax on payments to contractors and subcontractors without deductions for various construction activities including drilling wells.

The Navajo BAT and BAT Construction Tax apply to activities on the Navajo Reservation and in areas outside the reservation if such areas meet the definition of "Indian country". The proposed project would not be located on the Navajo Reservation. However, the BAT could apply to the project's gross receipts if it is determined that the project would be within Indian country. The definition of Indian country is vague

Table 4-25. McKinley County's annual property tax revenues compared to potential property tax revenues from the proposed project

	Market value	Taxable value	Estimated annual tax	Percent of annual McKinley County property tax outside Gallup
McKinley County taxable value outside Gallup		$358,246,865		
Equipment for Church Rock	$6,473,000	$2,157,667	$36,680	0.60%
Equipment for Crownpoint	$5,340,000	$1,780,000	$30,260	0.50%
Equipment for Unit 1	$4,447,000	$1,482,333	$25,200	0.41%
Production Value at $13/lb.				
Lbs.				
500,000	$6,500,000	$3,250,000	$100,175	0.91%
1,000,000	$13,000,000	$6,500,000	$200,350	1.81%
2,000,000	$26,000,000	$13,000,000	$400,699	3.63%
3,000,000	$39,000,000	$19,500,000	$601,049	5.44%
Production value at $15.70/lb. (October 1996 spot price)				
500,000	**$7,850,000**	**$3,925,000**	**$120,980**	**1.10%**
1,000,000	**$15,700,000**	**$7,850,000**	**$241,961**	**2.19%**
2,000,000	**$31,400,000**	**$15,700,000**	**$483,921**	**4.38%**
3,000,000	**$47,100,000**	**$23,550,000**	**$725,882**	**6.57%**
Production Value at $20/lb.				
500,000	$10,000,000	$5,000,000	$154,115	1.40%
1,000,000	$20,000,000	$10,000,000	$308,230	2.79%
2,000,000	$40,000,000	$20,000,000	$616,460	5.58%
3,000,000	$60,000,000	$30,000,000	$924,690	8.37%
McKinley County residential taxable value		$23,979,057		
Gallup residential taxable value		$98,793,730		
Assume new housing: 15 relocations at $100,000 per house	$1,500,000	$500,000	$15,412	

[a]Based on a 10-year average for the undepreciated taxable value.

Source: Kevin Rudolph, Finance Director, McKinley County, tax year 1996. Estimated annual tax is based on the McKinley County tax rate applied to the estimated taxable value of the HRI equipment and production value.

Table 4-26. Distribution of McKinley County property tax revenues

Distribution of property tax revenues	Tax rate for 1996	Annual revenue from proposed project assuming property value of $12 million
State debt service	0.001556	$18,672
County	0.013416	$160,992
School district	0.010851	$130,212
Other (vocational education, local colleges, and the Rebohoth Christian Hospital)	0.005	$60,000

and may ultimately be determined through litigation. However, there is precedent that could apply to HRI's proposed project because the BAT is currently collected on a coal mining project which, like the proposed project, is located within the Eastern Navajo Agency but outside the Navajo Reservation (Van Dyke 1996j). The effective tax on the coal mining project after various deductions has been about 3 percent of gross receipts (Van Dyke 1996j). Table 4-27 presents estimates of potential Navajo tax collections based on various assumptions about the sale of yellowcake from the proposed project.

Tax revenues collected by the Navajo Nation would not be legally designated for the benefit of the Crownpoint or Church Rock chapters or surrounding communities. All government funding to the chapters comes from the central Navajo Nation authority, but chapters where revenue-producing activities occur are likely to receive a higher than proportional benefit from taxes collected on the activities (Van Dyke 1996i). However, the Navajo Nation Tax Commission has indicated that distributions of tax collections to chapters is normally through capital improvement projects and that any higher than normal distribution to Crownpoint would depend on the Navajo Nation's demand for resources (Van Dyke 1996j).

Therefore, tax payments to the Navajo Nation could benefit the entire Navajo community in northwestern New Mexico and northeastern Arizona, which could indirectly benefit the local communities because of their dependence on public services provided by the Navajo Nation.

The potential contribution of the proposed project to the Navajo Nation would be a significant part of Navajo Nation tax revenues. However, Navajo Nation tax revenues from the project would depend on unresolved legal issues related to taxing jurisdiction. Table 4-27 indicates that the Navajo Nation could receive significant revenues from the project if it has the legal jurisdiction to do so.

4.9.5.3 The State of New Mexico

The State of New Mexico would impose a 3.5 percent severance tax and a 0.75 percent natural resources tax on the sales price of yellowcake from the proposed project. The severance tax would raise revenue at a rate about 17 percent higher than shown in Table 4-27. The natural resources tax would raise 25 percent of the revenue shown in Table 4-27. Together, these taxes would raise $1.5 million annually on 2 million pounds of yellowcake at $20 per pound.

Table 4-27. Potential Business Activities Tax payments to the Navajo Nation from the proposed project

Production (lbs.)	Market value	Estimated annual tax at 3 percent effective rate
Annual Gross Receipts (Production Value = $13/lb)		
100,000	$1,300,000	$39,000
300,000	$3,900,000	$117,000
500,000	$6,500,000	$195,000
1,000,000	$13,000,000	$390,000
2,000,000	$26,000,000	$780,000
Annual Gross Receipts (Production Value = $15.70/lb; October 1996 spot price)		
100,000	**$1,570,000**	**$47,100**
300,000	**$4,710,000**	**$141,300**
500,000	**$7,850,000**	**$235,500**
1,000,000	**$15,700,000**	**$471,000**
2,000,000	**$31,400,000**	**$942,000**
Annual Gross Receipts (Production Value = $20/lb)		
100,000	$2,000,000	$60,000
300,000	$6,000,000	$180,000
500,000	$10,000,000	$300,000
1,000,000	$20,000,000	$600,000
2,000,000	$40,000,000	$1,200,000

[a]The Business Activities Tax is 5 percent after deductions. The average effective rate has been about 3 percent on the pre-deduction valuation.

4.10 AESTHETICS

Construction and operation of the proposed project would disturb the vegetative communities and landscapes where well field construction and development would occur. However, these lands should recover under reclamation at the project's conclusion.

The landscapes created by hundreds of years of Native American occupation in the project area reflects their visions and experiences. The grazing of livestock, especially sheep, has altered the natural landscape so that the overgrazed, rolling sparse grasslands interspersed with piñon pines or junipers is now the landscape anticipated by residents. Navajo residents have had mixed negative and positive experiences with past uranium mining. These feelings about uranium mining necessarily color their interpretation of the aesthetic impacts of the proposed project, no matter how temporary those impacts.

4.10.1 Alternative 1 (the proposed action)

4.10.1.1 Construction

Most impacts on aesthetic resources would result from well field construction. Building and facilities construction would generally be minor in scale and intrusion. Additional construction impacts would include noise and dust from clearing for parking, access roads, well sites, storage pads, retention or evaporation ponds, and monitoring rings.

Land areas totaling over 70 percent of the three project sites have been or would be disturbed by vehicular traffic and activities in the well fields, trunk lines, and storage areas. These disturbances would occur sequentially, over the life of the project. During construction, only about 24 ha (60 acres) would become restricted at any given time in each site. Smaller subsets of that area would then be only sequentially disturbed. HRI's reclamation plans should restore these disturbed lands to original conditions (i.e., reclaimed and revegetated, but most likely subject to the same intensive grazing pressures as the surrounding lands).

Drilling would be conducted 12 hours per day at the Church Rock site, but would be conducted 24 hours per day at the Crownpoint and Unit 1 sites because of the greater depth to the ore zone. This could create a nighttime aesthetic impact in that the drill rigs would be lighted and would generate some noise (standard diesel engine noises associated with conventional construction activities—about the same as that from water-drilling operations or from a large bulldozer). Lights on drilling rigs would be most visible—and incongruous—from elevated areas.

HRI estimates that it would need four or more drilling rigs at each site. HRI experience indicates that well fields can be placed into production at about 2 ha (5 acres) at a time. This means the drilling activity would be concentrated in only a small percentage of each project site at any one time and would have only temporary impacts. Actual boundaries of areas to be mined would not be known until final exploration prior to initial mining and ahead of the evolving knowledge of the ore frontier. Precise locations of drilling sites would not be known until the project were to commence. Planned access roads, pipelines, and potential locations of retention ponds would similarly be variable within each project site.

Construction of the process facilities at the Unit 1 site would be visible, but they would use materials and be painted to blend in with the surroundings. The facilities would be removed upon completion of project operations.

HRI states that it would not disturb any juniper or piñon pines found in the upper elevations of the project sites. Because these species are such slow-growing (1–2 centimeters in trunk circumference every 10 years), long-lived trees (300–400 years), avoidance would help maintain the pre-project appearance of the landscape during mining and provide a strong visual foundation for restoration of the project lands' aesthetic quality after mining.

4.10.1.2 Operations

The network of pipes and cables associated with the proposed project would be most visible from elevated locations. Because of the rolling topography of most potential well sites, project operations would be

variably visible, depending on observer position, intervening topography, distance, and lighting considerations. White pipes would not always be used, and some of the pipes would be buried for weather protection. The network of pipes and wells would not be regular in pattern or appearance (i.e., not a grid).

Only the processing plants would be a prominent feature of the landscape, and the largest potential facility—the main processing plant at Crownpoint—already exists. Because well fields would be phased into operation in conjunction with exploiting the ore front, there would never be a large expanse of land undergoing the mining processes at one time.

Unit 1 and Crownpoint operations would be highly visible from many locations in and around Crownpoint. Church Rock operations would be readily visible only from Route 566. Later-stage development of the Crownpoint site along the eastern-most portions of the site would be easily visible from Route 371, which carries some through traffic going to or from the Chaco Culture National Historic Park.

What visibility of the proposed project might mean to local residents or visitors is speculative. For those opposed to uranium mining or believing that the rewards of mining are distributed unjustly or that the risks are too high, the network of pipes, wells, vehicles, and processing facilities could become a near-constant reminder of the implications of the project. To the extent that the land might be seen as not supporting Navajo life, it may be seen as *not beautiful* (see Section 3.8). Other potential meanings (e.g., the potential for emigration from the area or the potential for selective "non-inmigration" by those offended by the presence of the mining operations) are possible, but too speculative to quantify.

4.10.1.3 Reclamation

Once project operations are completed, all facilities would be removed. With time, the reclamation efforts should result in no permanent impacts to aesthetic resources.

Species selected for reseeding should be adapted to the climate and soil conditions extant on the project sites, using forage characteristics of palatability, tolerance to grazing, and availability of year-round use (Thames 1977). HRI has stated that it would not disturb lands on steep slopes, so revegetation should not be necessary in these areas.

Staff recommends that at least 90 days prior to commencing any land-disturbing, land-clearing, or spoil-producing activities, HRI apply for relevant resource agency approval and, upon approval, develop a plan to revegetate all disturbed areas. The plan should include at a minimum:

1. a description of the plant species to be used, including each species' habitat and food values;
2. planting densities and methods;
3. fertilization, mulching, and irrigation requirements;
4. a monitoring program to evaluate the effectiveness of the plantings;
5. a description of procedures to be followed if monitoring reveals that the revegetation is not succeeding; and
6. an implementation schedule that provides for revegetation as soon as practicable after completion at a particular portion of well field and the filing of periodic monitoring reports.

The major limiting factor to establishing vegetation in the project area would be available moisture. Timing of seeding is critical in New Mexico, and should generally be synchronized with the highest expected precipitation (July, August, and September in McKinley County). Thus, coordinating revegetation efforts with the completion of various well field operations would necessarily involve tradeoffs in terms of speed of revegetation. Fencing established to control security during operations should be retained until revegetation is established.

4.10.1.4 Regional and Cumulative

Because the impacts of project construction and operation at the three sites are expected to be minimal and temporary, regional and cumulative impacts from the project are likely to be limited and primarily associated with the rate of reclamation to productivity of the disturbed lands.

4.10.2 Alternative 2 (modified action)

Construction and operation of an ISL uranium project under the modified action alternative would result in aesthetic impacts similar to those of the proposed action. The nature and extent of the differences would depend on the alternatives chosen. Obviously, limiting well field construction and operation to just two of the three proposed sites would lessen the likely extent of aesthetic impacts by limiting the affected areas. Mining in the Church Rock area would have the least aesthetic impact because mining has already occurred in the area, it is remote, and ownership patterns are less likely to embitter viewers.

Because none of HRI's liquid waste disposal methods would be expected to cause substantial impacts to aesthetic resources, selection of only one or two methods would not likely result in changes in impacts. Reinjection would cause the least negative aesthetic impacts, with evaporation ponds creating the most. Ponds would appear hard-lined and incongruous with the surrounding landscapes at each of the proposed sites. They are least objectionable at Crownpoint because of the light-industrial character of the site and existing ponds. Reclamation of the ponds would take more time, but should be able to be accomplished such that the resultant landscape could appear comparable to the pre-mining condition.

4.10.3 Alternative 3 (no action)

The no action alternative would result in no change to existing aesthetic resources at the three project sites. No additional lands would be disturbed, and the areas would continue to provide low-to-moderate quality vegetation communities for grazing activities.

4.11 CULTURAL RESOURCES

4.11.1 Alternative 1 (the proposed action)

Archaeological resources of varying quantity and quality from the Anasazi culture have been identified at all three project sites. Other archaeological resources undoubtedly exist at the sites and are susceptible to potential impacts from ground disturbance during construction and operation of the project. Numerous archaeological resources that may be of such significance as to justify their consideration for inclusion on

the National Register of Historic Places are likely to be present in the Unit 1 and Crownpoint sites (Marshall 1991; Marshall 1992).

Historic resources at all three sites include various Navajo artifacts, none of which is considered to be eligible for inclusion on the National Register. Some artifacts of Anglo culture also have been identified, but they are not considered to be culturally important.

Traditional cultural resources, including sacred sites, sites associated with life cycle rituals, prayer offering places, plant gathering locations, and important landscape formations, were the subject of separate investigations conducted by traditional Navajo practitioners and local informants. No such resources were identified at the three project sites, and the closest cultural resource sites were at least 1 mile away and out of line-of-site from the project sites. No impact should occur to those off-site traditional cultural resources as a result of the proposed project.

Damage to cultural resources typically occurs through such human activities as removal of artifacts, destruction of walls or ceilings of structures, plowing, mining, construction excavation, irrigation, and livestock herding. Damage can be incidental to other activities or intentional through looting or vandalism. Damage to the scientific understanding of such resources can occur through simply moving an artifact from its original location. Such movement destroys the archaeological "context" in which the artifact might have been better understood as a component of the overall culture. Damage to cultural resources can also occur through natural events, such as wind, rain, flooding, extreme heat or cold, burrowing by animals, insect activity, and fire. Considerable damage from natural causes has occurred to cultural resources in the three project sites, to the extent that almost all pre-Navajo resources are indiscernible to the untrained observer. They are typically bare outlines of walls at ground level, eroded mounds of soil, or potsherds scattered about on the ground. Blowing soil and occasional floods have covered up the sites over the centuries.

Potential threats to cultural resources from HRI's proposed project primarily are posed by earth moving, incidental pedestrian and vehicle traffic, and looting following the identification of sites. Relatively little looting is believed to have occurred at the three sites to date because Navajo reside near or on the sites, thereby discouraging "pothunters."

Adverse impacts of the proposed project on cultural resources would be reduced or eliminated by the policy of avoidance set forth in the HRI's *Crownpoint Project Cultural Resource Management Plan*. This plan describes how HRI would ensure preservation of all archaeological, historical, and traditional cultural resources, including gravesites. The plan's objective is to avoid contact with all such resources by identifying their locations through intensive, Class III surveys and flagging all such locations as protected zones where human activity will be prohibited. This policy is regarded as feasible since ISL mining allows for considerable flexibility in the layout of facilities.

Prior to any future surveys, oblique, low-sun-angle aerial photographs of suspected cultural resources, such as Anasazi roads, would be taken to aid pedestrian surveys. Archaeological testing involving digging test holes at selected, potentially affected sites would occur before construction, and archaeologists would be on site at all times when construction is in progress.

Even with these precautions, the possibility exists that subsurface artifacts or unmarked graves could be unearthed. In the event that cultural resources are unintentionally unearthed, construction work would cease

and the artifacts or human remains would be evaluated for their significance. HRI's *Cultural Resource Management Plan* establishes a policy of avoiding contact with and removal of cultural resources. In the event that cultural resources are inadvertently uncovered, they would be evaluated in accordance with applicable laws and regulations including the Archaeological Resources Protection Act, National Historic Preservation Act, American Indian Religious Freedom Act, Native American Graves Protection and Repatriation Act, Navajo Nation Policies and Procedures Concerning the Protection of Cemeteries, Gravesites, and Human Remains, as well as policies of Puebloan tribes claiming descent from the Anasazi culture in the event Anasazi gravesites are discovered.

4.11.2 Alternative 2 (modified action)

In the modified action scenario, one or two of the proposed project sites, but not all three, would be developed. The location of the main processing facility could be changed from the Crownpoint site to the Church Rock or Unit 1 site or to a processing facility elsewhere out of the Crownpoint region. Lastly, liquid waste disposal methods could be changed to various combinations of evaporation ponds, injection wells, land application, and surface discharge.

4.11.2.1 Alternative Sites for ISL Mining

With respect to developing only one or two sites rather than three, impacts to cultural resources would be expected to decrease proportionately. Less land would be subjected by mining and fewer cultural resources would be identified or inadvertently damaged by equipment, personnel, or even looting or vandalism. There is no indication that more extensive development would occur at developed sites that would hinder the HRI's plan to avoid disturbing cultural resources. Thus, it does not appear that increased risk would occur to resources in those sites that would be developed.

4.11.2.2 Alternative Sites for Yellowcake Drying and Packaging

Changing the location of the main processing plant from Crownpoint to one of the other two sites or to an existing site elsewhere should not affect cultural resources. The processing unit would add only a small addition consisting of a yellowcake drum storage area, dryer room, office and shower to either of the satellite facilities at the other two sites selected for the processing facility. This minor addition would require a very small increment of land for the expanded plant. Using an existing processing plant elsewhere in New Mexico or Texas would create no additional cultural resource impacts.

4.11.2.3 Alternative Liquid Waste Disposal Methods

Different combinations of evaporations ponds, deep-well injection, land application, and subsurface discharge could affect the level of impacts to cultural resources. Generally, the more land required for a liquid waste disposal method, the greater the potential risk to cultural resources. As noted in Section 3.9, cultural resources are prevalent from the Anasazi culture, and more are likely to be found during more thorough pedestrian surveys, when archaeological testing is carried out, and during earth moving operations. With methods that use larger evaporation ponds or require more land area for surface discharge or land application, the risk of coming in contact with more resources is increased. In addition, the flexibility to move such locations around to reduce adverse impacts is lessened because of size and

configuration constraints. Thus, use of alternative liquid waste disposal methods appears to pose the greatest risk of increasing adverse impacts of any of the three categories of project modifications.

4.11.3 Alternative 3 (no action)

The no action alternative would leave cultural resources in place at the three project sites and unaffected by any mining development. Thus, no adverse impacts would be attributable to the proposed action. Conversely, no new cultural resources would be discovered and identified that might assist archaeologists in gaining new knowledge about ancient cultures. Although HRI proposes to leave such resources alone, the act of uncovering and/or identifying resources as important enough to be left alone or protected has consequences for scientists.

4.12 ENVIRONMENTAL JUSTICE

The approach used in this environmental justice analysis is based on guidance from NRC and CEQ as outlined in Section 3.10. A significant environmental justice impact is an impact to human health or the environment that is high and adverse and disproportionately affects a minority or low-income population. Because the population near the proposed project sites is comprised almost entirely of Navajo, many of them living in poverty, any significant adverse impact resulting from the project would be an environmental justice impact. Other effects of the project that would be below significance levels in other locations may also have environmental justice implications.

The following sections summarize the potential impacts of the proposed project and discuss the relevant mitigation measures intended to reduce their consequences. Additional mitigation measures are proposed to reduce the local communities' sensitivity to the project. Because impacts to air quality (Section 4.1), geology and soils (Section 4.2), and land use (Section 4.8) are negligible and have caused little or no concern among the local populations, they are not discussed in this section.

4.12.1 Groundwater

Significant adverse effects to groundwater quality would result if an excursion (either horizontal or vertical) occurs or if, after routine mining, water quality is not restored.

Successful restoration of a production-scale ISL well field has not previously occurred. Further, site-specific tests conducted by HRI have not demonstrated that the proposed restoration standards can be achieved at a production scale. Therefore, to preserve the community's use of the Westwater Canyon aquifer as a drinking water source, staff recommends that several mitigation measures be required of HRI. The distance between proposed mining activities and the community's water supply wells drives these measures (see Section 4.3).

- First, HRI must conduct a groundwater restoration demonstration at the Church Rock site before lixiviant is injected at either the Unit 1 or Crownpoint sites. If restoration to standards discussed in Section 4.3 is not achieved, mining at Church Rock would cease and no mining would be allowed at either the Unit 1 or Crownpoint sites.

- Second, before lixiviant is injected at Unit 1, HRI must provide bonding to cover the cost of replacing BIA and NTUA water wells that serve the Crownpoint community and the surrounding area, the costs of pipeline construction required to serve the community from the new wells, and for the cost of making the existing delivery systems compatible. Should restoration fail or an excursion occur, the community then would have the financial capability to develop a replacement water system that provides water of equal quantity and having quality that meets EPA and Navajo Nation Water Code standards.
- Third, before lixiviant is injected at Crownpoint, the BIA and NTUA water wells that serve the Crownpoint community and the surrounding area must be replaced, pipeline must be constructed, and the BIA and NTUA systems must be linked, all to be funded by HRI. Regulatory authorities, including the Navajo Nation Division of Water Resources and the Navajo Nation Environmental Protection Agency, and the Navajo Tribal Utility Authority, will determine the appropriate placement of the wells in discussions with HRI.

The groundwater analysis in Section 4.3 concludes that water consumption impacts would be significant during groundwater restoration activities. The maximum drawdown in the affected aquifer is 80 feet. This drawdown would not affect water availability to the community, but it would increase the cost of pumping water from the aquifer. Therefore, in Section 4.3 staff recommends the following mitigation:

- When groundwater restoration activities begin at a production-scale well (excluding the smaller-scale Church Rock demonstration), HRI must bond for the projected increase in costs of pumping water from the BIA and NTUA water wells that serve the Crownpoint community and the surrounding area.

Section 4.3 discusses actions that would be taken in the event that an excursion occurs. In addition to those actions, the following must occur:

- NRC would notify the head of the Navajo Nation Department of Environmental Protection of the excursion by telephone within 24 hours of receipt of notification of an excursion. NRC would provide the Navajo Nation with copies of the notification-of-excursion letter and the written report describing the excursion and corrective actions immediately upon their receipt.
- In the event that the excursion is uncorrected within 60 days, NRC would inform the Navajo Nation of the action (termination of injection or increased bonding) within 67 days of verification of an excursion.

The established goal of groundwater restoration efforts would be to return all parameters to average pre-mining baseline conditions (the process for identifying baseline conditions is discussed in Section 4.3). Secondary goals are in effect if "reasonable" restoration efforts fail to achieve pre-mining baseline conditions. "Reasonable" efforts would be defined as follows:

- Before the groundwater restoration demonstration at Church Rock occurs, NRC would consult with regulatory authorities, including the Navajo Nation Environmental Protection Agency, to define "reasonable" efforts. The Navajo Nation EPA must concur with the definition.

An injection well permit (or permits) under the federal Safe Drinking Water Act, the New Mexico Water Quality Act, and/or the Navajo Nation Water Code would be required. Although permitting for the

proposed action occurs separate from the EIS process, permitting issues have arisen in the NEPA context. Because these issues have heightened the community's sensitivity to the project, they are addressed here.

The U.S. EPA has a direct implementation program for all "Indian Country" as defined in 18 U.S.C. Section 1151 (see 40 CFR Section 144.3). However, the Navajo Nation has qualified for "treatment as a state" under the terms of the federal Safe Drinking Water Act and is developing its own regulatory program, including policies regulating ISL mining. This program may supplant the U.S. EPA regulatory program within four years. The State of New Mexico is an agreement state with primary enforcement responsibility for all of New Mexico except "Indian lands," which has been interpreted by U.S. EPA to mean Indian Country.

There are competing claims for permitting jurisdiction over Section 17 of the Church Rock site. HRI holds a New Mexico Water Quality Act permit for the entire Church Rock site. The Navajo Nation claims jurisdiction over Section 17, and the U.S. EPA recognizes the Navajo claim. Jurisdictional conflicts are equally likely on other areas of the project sites. It is not the function of this EIS process in particular or the NRC in general to arbitrate among the competing jurisdictional claims. However, NRC staff has determined that certain issues must be considered in resolving this regulatory authority issue. The first is adherence to 40 CFR 144.2, which requires U.S. EPA to consider the following in promulgating a UIC program on Indian lands: "(a) the interest and preferences of the tribal government having responsibility for the given reservation or Indian lands; and (b) the consistency between the alternate program and any program in effect in an adjoining jurisdiction." The second issue to consider is tribal sovereignty and the need to assure environmental justice. Based on these considerations, and because the proposed action would occur in an area traditionally held and currently occupied mostly by Navajo people and some of the land is indisputably "Indian Country," NRC would take the following action:

- NRC would work with the U.S. EPA, the state, and HRI to assure that the Navajo Nation be involved in the UIC permitting and regulation of HRI facilities. Specifically, the Nation (particularly the Navajo Nation Environmental Protection Agency) should be a party to all negotiations regarding UIC licensing and regulation and must concur with the agreement reached in negotiation. However, the outcome of such negotiations (particularly the designation of a lead agency) would affect only the regulation of the proposed action and is not to be construed as having implications for other jurisdictional disputes.

The conclusion of the water consumption analysis—that the proposed project would not significantly affect availability of water to the community—is contrary to perceptions of the project that have been voiced in the scoping process for this EIS. Throughout the western United States, water availability and possession of water rights is a contentious issue. The contention is worsened in this case because a second issue is involved, that of jurisdiction in determining the nature and ownership of the water rights. The two sovereigns at odds are the State of New Mexico and the Navajo Nation.

With respect to the Church Rock site, the state's district courts have upheld the state engineer's authority to grant and administer water rights (specifically, over UNC's application to revise an existing right it holds). The state court held that the two sections proposed for development at the Church Rock site (sections 8 and 17) are not Indian Country. The Navajo Nation asserts that any claim of jurisdiction by the state engineer over water rights in tribal trust lands and Indian Country interferes with tribal sovereignty. The Nation asserts its jurisdiction over water rights in Indian Country through the Navajo Nation Water Code.

To date, HRI (or its grantor UNC) does not have the water rights that would be required to conduct ISL mining at any of the three sites. At the Church Rock site, the state engineer, in a decision upheld by the state courts, has determined that the existing right held by UNC is insufficient to meet the needs (for water diversion and consumption) of HRI's proposed operations. HRI has not sought the water rights for the Unit 1 or Crownpoint sites because jurisdiction over water rights at these sites has not been resolved.

As in the case of the UIC permit, it is not the role of this EIS process in particular or the NRC in general to arbitrate among the competing jurisdictional claims. However, the NRC as an agency of the federal government has an obligation to recognize and protect the tribal sovereignty of the Navajo Nation. In addition, the context and mandates of environmental justice suggest that the Navajo Nation (because Navajo people would potentially be affected) should be involved in the water rights granting process. To this end, staff recommend the following:

- HRI must facilitate negotiations between the State of New Mexico (i.e., the state engineer) and the Navajo Nation (i.e., the Division of Water Resources) that would develop an approach and process through which HRI's applications for water rights would be considered. The Navajo Nation must be in concurrence with the outcome of these negotiations. The implementation of any agreement reached as a result of negotiations for the proposed action should not be construed as having implications for other jurisdictional disputes over water rights.

4.12.2 Surface Water

Minimal impacts to surface water are expected during well field construction and operation.

Discharge of restoration water to surface water bodies is a disposal option possible only at the Church Rock site (Section 4.4.1.3). The expected average uranium concentration of the liquid waste to be discharged to surface water bodies is greater than allowable concentrations (10 CFR Part 20, Appendix B; see Section 4.6.2.3). If a variance is obtained and surface water discharge occurs, exposures to individuals who drink the water prior to full mixing in the stream could result in an individual dose that exceeds the 1 mSv (100 mrem) limit. Exceeding a regulatory limit is considered a significant adverse effect of this liquid waste disposal method. This alternative would, therefore, result in a significant environmental justice impact.

The conservative scenario that results in the individual dose is a highly unlikely occurrence because individuals are not likely to drink from the river at the wastewater discharge site. However, the local population is known to drink directly from the Rio Puerco and to water their livestock there. The livestock provide milk and meat for their owners. Because of these subsistence activities, it is possible that individual doses could be much higher to the Navajo population than they would be to another population that did not participate in such subsistence activities. Further, this same stream was previously contaminated by a mill tailings dam break and mine de-watering effluent discharge. Cumulative exposures to the population using the water are an important consideration under NEPA. To provide maximum protection to the local population, staff recommends that this alternative be excluded from further consideration.

Any potential effect from other wastewater disposal options (i.e., land application and evaporation ponds) should be conducted employing the following mitigation measures, which are intended to provide additional protection for the local community.

- The most stringent wastewater disposal standards of the three potential regulating agencies—the U.S. EPA, the State of New Mexico, and the Navajo Nation—would apply to the discharge water.
- Should land application be planned for any land other than privately-owned or state land, NRC would work with the U.S. EPA and HRI to assure that the Navajo Nation is involved in land application permitting. Specifically, the Nation (particularly the Navajo Nation Environmental Protection Agency) would be given an opportunity to comment on the land application proposal and must concur with the provisions of the permit.

4.12.3 Transportation Risk

The transportation risk analysis in Section 4.5 considered the high rate of accidents on highways near the project sites, a particular concern expressed by many commentors in scoping and the DEIS public hearings. The analysis concludes that there is only a very slight chance of an accident involving the trucks delivering chemicals to the sites and transporting uranium slurry and yellowcake from the sites. The likelihood that the accident would result in a materials spill is small; an even smaller likelihood exists that a spill would affect human health. However small the chance, an accident could occur and could result in the fatalities of those involved. It is probable that the victims of a local accident would be Navajo community members. Mitigation measures that could reduce these small risks even further are as follows:

- All delivery trucks used to transport project materials (uranium slurry, yellowcake, and process chemicals) must carry the appropriate certifications of safety inspections.
- All delivery truck drivers must hold appropriate licenses.
- HRI employees may be subjected to random "breath-a-lizer" tests. HRI would contract for such tests to be conducted randomly—but, minimally, once every six months—on all its drivers.

4.12.4 Health Physics

No alternative—with the exception of wastewater discharge into surface water bodies (see Section 4.12.2)—would exceed allowable limits for radiation exposure to the public. Further, the increase in total effective dose equivalent is only slightly higher (well below a 1 percent increase) than the dose received from natural background radiation. This low total effective dose equivalent would occur even if a family were to farm and herd animals on a land application site immediately after wastewater application ceased.

The model used to predict health physics impacts accounts for exposures possible from being outdoors much of the time and for consuming vegetative matter and animals affected by the project. Also, the dose assessment considered doses to infants, because they are more sensitive than the adult population.

The proposed project would result in a positive environmental health effect at the Church Rock site. This effect would occur because some areas of the site have higher concentrations of residual radioactivity (from previous mining activities) than would be allowed in decommissioning the site under the proposed action. These areas would be cleaned up as part of the well field decontamination.

The analysis in Section 4.6.1.4 considers the cumulative effect of the long history of uranium mining in the area and the large exposures to radon (and other radioactive elements that form as radon decays) that occurred primarily to miners and resulted in a high incidence of cancer among them. It concludes that the

proposed project would result in a negligible increase to existing impacts to the area due to mining and milling.

NRC is aware that to some members of the local community any increase in the cumulative effect or in radioactivity brought to the surface by any uranium mining activity would be unacceptable. This perception is likely to be most prevalent among those who have or have family members or friends whose health has been negatively affected by uranium mining activity.

4.12.5 Ecology

No significant impacts to wildlife and vegetation in the area are expected, although some localized habitat disturbance may result from construction activities. It is possible that waterfowl would using the retention ponds as stopovers during migration. The analysis in Section 4.7 concludes that concentrations of harmful substances in wastewater retention ponds would not be high enough to harm any birds that use the ponds.

Although information about the local population's subsistence consumption of migrating birds is unavailable, it is highly possible that some birds would be consumed. To minimize any potential health consequences of the consumption of birds and to protect the birds themselves, staff recommends the following mitigation be implemented as soon as possible if birds begin to use the ponds:

- Bank vegetation that would provide cover for the birds would be removed, and visual or sound devices would be installed to ward off birds. If these measures fail to keep birds from the ponds, wire screens would be placed over the water's surface.

4.12.6 Socioeconomics

The analysis of socioeconomic impacts in Section 4.9 indicates that the proposed project would have a positive effect on the local economy primarily due to the jobs that would be available to local Navajo. To assure that local Navajo are provided job opportunities, staff recommends the following mitigation measures:

- HRI, with input from and review by officials of the six local chapters (see Section 4.9), would develop a hiring plan that outlines how members of local chapters would be informed of job opportunities in a timely manner.
- HRI would provide an annual report to NRC and the six local chapters indicating the number of employees who are Navajo, their chapter affiliation, and the number of non-Navajo employees.

HRI has made commitments for equipment and training to be provided to the local hospital and fire department so that they are prepared and equipped to respond should an accident occur and that the hospital's future delivery of service would not be affected by handling a decontamination case. These commitments are outlined in Section 4.9.

4.12.7 Cultural Resources

The cultural resources analysis (Section 4.11) concludes that, given the available information and HRI's plan of "total avoidance," no significant impacts to cultural resources are likely. Additional, specific

mechanisms to prevent impacts to cultural resources may be developed during the National Historic Preservation Act Section 106 consultation process.

Some Native Americans hold spiritual or religious beliefs that any mining activity upsets the balance among nature, people, and their creator. It is difficult to determine the significance of such an impact, either in terms of cultural resources or environmental justice. Staff recommends the following mitigation to help minimize such concerns:

- HRI's cultural resources specialist must consult with traditional practitioners of both the Crownpoint and Church Rock chapters to ascertain whether specific ceremonies or blessings are in order. Based on these consultations, the cultural resource specialist must identify those ceremonies whose conduct must be facilitated by HRI.

4.12.8 Process Components of Environmental Justice

Involvement of Native American tribes in a manner consistent with the government-to-government relationship between the United States and Native American tribes is essential to assuring environmental justice. A primary mechanism affording such involvement in NEPA is the role of cooperating agency. The Navajo Nation declined to participate in this EIS as a cooperating agency. However, the Nation and the Chapters have provided a considerable amount of information incorporated into the analyses of impacts. Also, the Navajo Nation and the Hopi Tribe participated in the scoping and public hearing processes, and their comments have been addressed both in the comment responses appended to this FEIS and considered in the analyses conducted for the FEIS.[1]

When the safety evaluation report for the proposed project is completed (projected for early spring 1997), NRC will issue its draft Record of Decision accompanied by proposed licensing conditions. A comment period of 45 days will be allowed. The licensing decision will be made after this comment period or after the hearings process is completed, whichever is later.

To fulfill its trust obligation to the Navajo people and to operate in a manner consistent with the government-to-government relationship maintained between the United States and Native American tribes, NRC staff have recommended mitigation measures (see preceding sections) that specify how the Navajo Nation would be involved in regulation and oversight of the proposed project and how it would be kept informed of events occurring at the project sites.

Native American groups that have ties to the project areas, in addition to the Navajo, are the Pueblos of Acoma, Laguna, and Zuni, and the Hopi Tribe. Interest in or concerns about the project that these Native American groups have expressed have focused on the potential for cultural resource impacts. The National Historic Preservation Action Section 106 review process provides opportunity for these concerns to be addressed and for participation of the concerned parties. Each of these groups, along with the Navajo Nation, are involved in the ongoing Section 106 consultations.

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[1]The Navajo Nation petitioned NRC for cooperating agency status in October 1996. Because the petition was made when the NEPA assessment process was coming to a close, the petition was denied.

The Navajo Nation's moratorium on all uranium mining activity is to be effective on Navajo lands until such a time that the Navajo people are assured that the safety and health hazards associated with uranium mining activity can be addressed and resolved. However, the Church Rock and Crownpoint chapters where the proposed project would be located held referenda indicating their support for HRI's proposal despite the moratorium. Also, given that many allottees have agreed to lease their land to HRI, the applicability of the moratorium to allotted lands is not clear. At issue is whether the Nation's moratorium overrides the individuals' decisions about their land. Abiding by the moratorium also conflicts with the federal Mining Law of 1872. Given these conflicts, the NRC has proceeded with the EIS process and with a "Safety Evaluation Report" to determine what impacts, including human health and safety, would result from HRI's proposed project and the alternatives. The Record of Decision, incorporating all license conditions, will be NRC's determination of whether the local community's safety and health can be reasonably assured.

NRC staff acknowledges that the technical information contained in this FEIS can be a challenge to native speakers of languages other than English. NRC has tried to facilitate communication during the scoping and public hearing process by providing translators. To facilitate local community member's understanding of the conclusions drawn in this FEIS, the summary report has been translated into Navajo. The Navajo-language summary report will be available within 30 days of the notice of availability of the FEIS (published in the Federal Register). Copies of the Navajo-language summary report will be provided to the Church Rock and Crownpoint Chapter Houses, and notices (in English and Navajo) posted at chapter houses will announce the availability of this FEIS.

4.12.9 Alternatives

The discussion in the preceding environmental justice sections applies broadly to the proposed action and all alternatives, except the no action alternative. To the extent that the impact analyses of each resource (e.g., groundwater, cultural resources) have concluded that lesser impacts would result from mining at one or two sites, but not all three, environmental justice impacts would also be reduced. The no action alternative would not result in any adverse impacts to the community. However, two benefits of the proposed action—the economic gain resulting from employment of local Navajo and the reduced radiation levels that would result from decontamination at the Church Rock site—would not occur.

5. COSTS AND BENEFITS ASSOCIATED WITH THE PROPOSED ACTION AND ALTERNATIVES

The proposed project would be a private venture and, as such, it would not have a public purpose such as flood control or environmental remediation. The purpose of HRI is to make a profit on its proposed investment in the mining and processing of uranium ore. The processed ore would ultimately be used as fuel in nuclear reactors to generate electricity. From HRI's perspective, the benefits of the project would be the revenues that could be generated from the sale of processed uranium. The costs would be the expenses, including the cost of land, labor, and capital, required to mine and process the uranium. Also, there would be costs to meet regulatory standards including environmental protection and restoration. The amount of revenue that the project would ultimately generate is subject to the uncertainty inherent in the market for uranium. The benefits and costs that are internal to HRI are not subject to government regulation and therefore are not assessed.

In economics terminology, "benefit-cost analysis" can be defined as a decision technique for evaluating public investments. Because the proposed project being evaluated is based on a private investment, this type of analysis is technically inappropriate. However, the basic insight of benefit-cost analysis can provide a framework for evaluating the advantages and disadvantages of the project from a social perspective. In this vein, this section takes the perspective of the benefits and costs of the project to the local communities that would be affected by and/or have jurisdiction over HRI's mining proposal. Benefits and costs would occur to members of the local communities, local governments, and the State of New Mexico. They would include changes that are brought about by HRI's proposed operation, including the expansion of tax bases related to the mining and processing operation and any additional demands on the infrastructure and public services that would be imposed by the project. They also would include the beneficial effects of project employment.

5.1 Benefits of the Proposed Project

The major potential benefits to the local community include benefits from employment income, royalty income, and taxes that would be generated by the mining operation. The project would develop little in the way of infrastructure, such as roads or buildings, that would be useful to the surrounding communities once the project is completed. It could provide some improvement to over-grazed lands by closing off grazing for a period of time while well fields are developed and operated. However, this would be a very small benefit because the land effected has only a very small value for grazing.

5.1.1 Potential Production

Both employment generated and taxes paid by HRI would be related to the production of yellowcake. The amount of yellowcake produced would depend on the market price and the cost of production. Table 5-1 shows HRI's projected costs of producing yellowcake for the alternative operations. Table 5-2 indicates the current price of U_3O_8 and the latest government projection of price through 2010. It should be noted that the spot-market price in October 1996 was $3 higher than the projected price for the same year. Over the

Table 5-1. Average production costs per pound of yellowcake under alternative project designs

Alternative configurations	Church Rock	Unit 1	Crownpoint
Haul loaded resin to other site for processing and drying	\$11.36	\$10.46	\$9.46
Ship yellowcake slurry to dryer at other site for drying	\$11.32	\$10.48	\$9.40
Ship yellowcake slurry to Texas for drying	\$11.83	\$11.05	\$9.87
Stand alone—all processing done at each site	\$11.30	\$10.51	\$9.38

Source: HRI, *Response to Request for Additional Information, Issue 92: Cost/Benefit Analysis*

Table 5-2. Projected price of U_3O_8

Year	Latest DOE/EIA spot market projection (adjusted to 1996\$)
Current price on spot market (10/21/96)	\$15.70
1996	\$12.72
1997	\$12.74
1998	\$12.62
1999	\$13.00
2000	\$13.31
2005	\$14.86
2010	\$17.38

Source: Uranium Industry Annual 1995 (DOE/EIA-0478(95). Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, U.S. Department of Energy, May 1996.

last ten years, the spot-market price has been very volatile, fluctuating from a high of over \$16 in 1987 to a low of less than \$8 in 1991. As late as 1995, the price was less than \$10 per pound.

With additions for taxes and royalties, HRI's costs could be 5 to 15 percent higher than projected in Table 5-1. This suggests that the Church Rock operation could become marginal if the price of U_3O_8 falls back to the projected prices shown in Table 5-2. The important point relevant to assessing the project's potential benefits to the local community is that they depend on HRI's costs being lower than the future price of U_3O_8, which has been quite volatile. If the price of U_3O_8 is less than the variable costs of operation, then operations may be discontinued. If this happens, there would be no economic benefits to the local community.

Table 5-1 points out several alternative production configurations for HRI. HRI's preferred alternative is to ship yellowcake slurry to one of the three project sites for drying and processing. The alternative of shipping yellowcake slurry to Texas for drying would have the lowest potential benefit to local

communities in New Mexico because it would require less employment for processing. Also, this alternative would have the highest cost because of the cumulative increase in risk of a slurry spill to local communities along the transportation route. The "stand alone" alternative is economically attractive to HRI and, relative to HRI's preferred alternative, would have slightly less risk of a spill on public roads used to transport yellowcake slurry, including Navajo 49 and New Mexico 371 and roads through parts of the town on Crownpoint.

5.1.2 Benefits from Employment and Royalty Income

The most important local benefit from the proposed project would be opportunities for employment and earnings. The degree to which the local communities benefit would depend on the available supply of qualified labor and HRI's hiring policies. Staff review indicates that about 100 long-term jobs may be available that would not require highly specialized experience or skills. It appears that members of the local communities could fill most, if not all, of these jobs. If trends similar to the rest of McKinley County are representative of the Navajo communities surrounding the proposed project, 47 percent of the population above 25 years has a high school degree or more, and about 7 percent have an associate, bachelors, or graduate degree (Rodgers 1992). Presently, there are seven students from the Church Rock Chapter and 72 students from the Crownpoint Chapter enrolled in the Crownpoint Institute of Technology (CIT) (Van Dyke 1996k). Enrollment at CIT is important because it demonstrates that local community members desire and receive training such as office administration and building trade skills that are relevant to employment opportunities with the proposed project.

It also appears that members of the local community would have the economic incentive to fill all the available jobs. In 1989, about 76 percent of Navajo households in McKinley County had incomes below $30,700 (adjusted to 1996 dollars), and 57 percent were below $18,400 (adjusted to 1996 dollars) (U.S. Bureau of the Census 1990). This indicates that the HRI jobs, which would average about $24,000 per year, would be very attractive to members of the local community. Based on the skill levels required and the attractive wages relative to existing opportunities, staff believes that up to 100 jobs could be filled by members of the local community depending on how well HRI executes its stated intention to hire local Navajo.

Table 5-3 indicates that Navajo earnings from the project could be up to about $2.4 million annually at the long-term operation level suggested by HRI. This level of operation is consistent with the production of about 1 million pounds of yellowcake annually from the Unit 1 operation and 1 million pounds of yellowcake annually from the Crownpoint operation. Table 5-4 presents a summary of the estimated benefits.

There could be about $1.1 million in annual royalty income going to holders of leases, depending on production from Unit 1 and the price of U_3O_8. However, this income would be concentrated (about 9 lease holders) and would probably not have a widespread effect. Some of the lease holders may be absentee land owners or, upon realizing a substantially increased income from the royalties, could choose to move from the area.

Table 5-3. Summary of annual community earnings

	Potential Navajo employment	Potential Navajo earnings
Church Rock (1997–2003)	44	$1,053,000
Unit 1 (1999–2016)	38	$905,500
Crownpoint (2001–2016)	47	$1,124,700
Peak	129	$3,083,200
Long Term (2003–2016)	100[a]	$2,400,000

Average total project earnings per HRI job: $28,000

Average local community earnings per HRI job: $24,000

[a]Includes 85 direct jobs for Unit 1 and Crownpoint from HRI and 15 jobs for drill rig contractor.

Source: See Section 4.9 of this FEIS.

5.1.3 Benefits from Tax Revenues

As indicated in Table 5-4, significant tax revenues would be collected by McKinley County and possibly the Navajo Nation. Although not shown in Table 5-4, the State of New Mexico could collect about $1.5 million annually from severance and natural resource taxes. The Navajo Business Activities Tax and Construction Tax apply to activities that occur on the Navajo Reservation and in areas outside the Navajo reservation that meet the definition of "Indian country". The proposed project would not be located on the Navajo Reservation. However, the gross receipts of the project may be taxed by the Navajo Nation if it is determined that the project is located within "Indian country". The local communities, such as the town of Crownpoint or the Crownpoint Navajo Chapter, do not have any taxing authority.

There is no direct connection between the various taxes that may be collected and the local communities. The best chance for local communities to benefit from tax collection is through the Navajo Nation, which funds local community capital improvement projects and public services. However, there is no legal requirement for the Navajo Nation to fund projects in a specific area based on tax collections from that area. Crownpoint would indirectly benefit from Navajo Nation tax collections because these revenues enhance the Nation's ability to provide services and Crownpoint is the center for providing many of these services within the Eastern Navajo Agency (see Section 3.9).

5.2 Costs of the Proposed Project

Table 5-5 presents the potential costs of the proposed project to the local communities. Infrastructure costs related to population changes would be insignificant because population change would be small. The local

Table 5-4. Annual project benefits

	Navajo Nation	Local Navajo communities	McKinley County/ Non Navajo
Employment	NA	Of 100 long-term jobs that would not require highly specialized skills, local communities could get up to 100 depending on how well HRI executes its intention to hire local Navajo.	Total estimated long-term jobs less those going to Navajo (about 40 if Navajo get 100).
Earnings	NA	Average annual earnings for local employees would be about $24,000.	Average annual earnings for management/technical positions would be about $36,000.
Royalties	None	$1,099,000 annually (assuming 1 million pounds of yellowcake produced annually from allotment leases at $15.70/lb.). This would be distributed among 9 lessors of Unit 1 properties.	None.
Taxes	$942,000 annually for Business Activities Tax (assuming 2 million pounds of yellowcake at $15.70/lb. and contingent on legal jurisdiction to tax).	Cannot tax.	$484,000 annually for real property tax (assuming 2 million pounds of yellowcake at $15.70/lb.).
	$15,000 for construction tax (assuming $500,000 in drill rig contracts).	Cannot tax.	$55,000 for personal property (based on value of assets at Unit 1 and Crownpoint.
Other benefits	NA	Several jobs related to income expenditure in local community or incidental services required by project.	Several jobs related to expenditures in the local community or incidental services required by project.

Source: See Section 4.9 of this FEIS.

communities would require increased emergency response and medical treatment capabilities because of the small risk of a slurry truck transport accident on public highways. HRI has indicated that it is willing to provide training and/or cover the costs of training for the Crownpoint health clinic (See Section 3.9). Similarly, HRI has made a written commitment to the Crownpoint Volunteer Fire Department to provide appropriate training and equipment to respond to a slurry truck accident (Section 3.9). Therefore, these requirements should not result in costs to the local community.

Table 5-5. Project costs to the local community

Public services	Crownpoint	Church Rock	Navajo Nation	McKinley County
Infrastructure related to population increases induced by employment.	No significant costs.	No significant costs.	No significant costs.	No significant costs.
Fire and emergency related to potential accidents on public roads.	Requires additional training to deal with potential transport accidents. HRI would supply or pay for training of emergency response and any costs for health care facility.	Covered by Crownpoint emergency services.	Covered by Crownpoint emergency services.	Covered by Crownpoint emergency services.
Risk of contaminating and/or degrading water supply.	Replacement wells and distribution system to be provided by HRI. Staff recommends that HRI be bonded for additional operating costs of $7,000 per year.	No risk to water supplies.	No risk to water supplies.	No risk to water supplies.

Source: The Staff.

The most significant risk of the proposed project to the local community is the potential for contamination or degradation of the local water supply due to ISL mining operations. HRI has indicated its willingness to replace the existing water supply wells with new wells that would provide equivalent water capacity from the same aquifer. Details of the conditions under which HRI would replace the existing wells have not been finalized (Sections 3.3 and 3.9).

The conditions under which HRI would replace the existing water supply system would determine the potential costs imposed on the local community. For instance, if the water supply was degraded but still met drinking water standards, this could impose a significant cost on the local community that may not be funded by HRI because it is not clear that HRI's commitment would replace the community wells under this condition. It is problematic to estimate the cost to the local community if the water supply meets drinking water standards but is degraded by the mining operations. However, the maximum cost can be defined as the cost to replace the wells to attain the same quality of water that is now utilized. Based on discussions with HRI, the one-time cost of replacing the existing wells and water delivery system would be about $500,000. Over a 30-year period, this would be an annual charge of about $40,000.

If HRI replaces the existing wells and water delivery system, the cost of increased operation and maintenance would be about $3,000 annually (Section 3.9). Regardless of whether wells are replaced, there would be an additional annual cost increase of about $4,000 due to lowered water tables if mining occurs at

Unit 1 or Crownpoint (Sections 3.3 and 3.9). The groundwater mitigation measures recommend that HRI be bonded for additional operating costs. If the costs are passed on to water customers, they would be about $9 annually per customer if the wells are moved or about $5 annually per customer if they are not.

5.3 Summary of Project Benefits and Costs

The primary benefit to the local communities would be through employment income. The magnitude of this benefit would depend on whether HRI effectively recruits and utilizes local labor. If an effective effort is made to employ local community members, it could result in about 100 jobs and $2.4 million in annual earnings during the combined operation of Unit 1 and Crownpoint over about 13 years. Royalty income of about $1 million annually during the operation of Unit 1 would also be significant. However, this income would be very concentrated and would go to only 9 allotment owners.

Tax revenues from the project would go to McKinley County, the State of New Mexico, and possibly the Navajo Nation. Although these tax revenues are potentially large, the local Navajo communities cannot tax. It is possible that tax revenues from the project collected by the Navajo Nation could result in increased capital improvement within the local communities. However, this is uncertain and would depend on financial and political considerations. There is no requirement that the Navajo Nation provide any special benefit related to where the taxes are collected.

The only significant costs to the local community would be related to changes in local water quality. HRI has offered to replace the water supplies that are at risk if necessary. HRI's offer would cover the cost of developing new wells and connecting these wells with the existing water system. Staff has recommended that HRI be bonded for additional operating costs that would result from water drawdown and moving the wells. If water quality is degraded but still meets drinking standards and the wells are not replaced by HRI, the replacement costs to the town of Crownpoint would be about $50,000 annually.

The proposed project would have a strong benefit/cost ratio and should be very attractive economically to the local community if two conditions are fulfilled. First HRI, must mitigate any effects on the local water supply by replacing the supply (if necessary) from an equivalent source at no cost to the community. Second, most, if not all, of the 100 jobs that do not require highly specialized experience or skills should go to members of the local communities. Because the local communities cannot tax, these jobs are the main vehicle through which the local communities can share in project benefits.

6. CONSULTATION AND COORDINATION

TO BE PROVIDED IN THE FEIS

7. LIST OF AGENCIES, ORGANIZATIONS, AND PERSONS RECEIVING COPIES OF THE FINAL ENVIRONMENTAL IMPACT STATEMENT

TO BE PROVIDED IN THE FEIS

8. REFERENCES

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APPENDICES

THE APPENDICES, INCLUDING:

NRC RESPONSES TO COMMENTS ON THE DEIS

SECTION 7 (ENDANGERED SPECIES ACT) CONSULTATION

SECTION 106 (NATIONAL HISTORIC PRESERVATION ACT) CONSULTATION

WILL BE INCLUDED IN THE FEIS