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Remedial Action Plan for the Codisposal and Stabilization of the Monument Valley and Mexican Hat Uranium Mill Tailings at Mexican Hat, Utah


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REMEDIAL ACTION PLAN
FOR THE CODISPOSAL
AND STABILIZATION
OF THE
MONUMENT VALLEY AND MEXICAN HAT
URANIUM MILL TAILINGS
AT
MEXICAN HAT, UTAH
FEBRUARY 1993

APPENDIX B TO THE COOPERATIVE AGREEMENT
NO. DE-FC04-83AL16258

URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT OFFICE
ALBUQUERQUE OPERATIONS OFFICE
DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO 87108

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ATTACHMENT 1

Executive Summary
EXECUTIVE SUMMARY

INTRODUCTION

The Mexican Hat tailings site is in San Juan County, Utah, two road miles southwest of the town of Mexican Hat on the Navajo Reservation. The Navajo community of Halchita is approximately 0.5 mile southwest of the site. The mill at the Mexican Hat site was operated from 1957 to 1965 by Texas-Zinc Minerals Corporation and the Atlas Corporation. Originally, two irregularly shaped tailings piles were located in the northeastern portion of the site. They occupied approximately 69 acres of the 235-acre designated site and contained approximately 2,575,000 cubic yards (cy) of tailings. The total amount of materials, including the tailings and windblown and waterborne materials, is estimated to be 2,810,000 cy.

The Monument Valley tailings site is on the Navajo Reservation in Arizona, 17 road miles south of the Mexican Hat disposal site. The mill at the Monument Valley site was operated from 1955 to 1968 by Vanadium Corporation of America and its successor, Foote Mineral Company. The mill buildings and milling equipment have been removed from the site; two tailings piles, concrete building foundations, and debris remain at the site. The two irregularly shaped tailings piles occupy approximately 28 acres in the center of the 100-acre designated site and contain 1,030,000 cy of tailings. The total amount of materials, including the tailings, contaminated soils beneath and around the tailings, and other contaminated materials, is estimated to be 1,100,000 cy.

REMEDIAL ACTION

Under the proposed action, the tailings and other contaminated materials from the Mexican Hat and Monument Valley sites would be consolidated into a single embankment at the Mexican Hat site. The stabilized pile would then be covered with a two-foot-thick radon barrier consisting of silty sands amended with 10 percent sodium bentonite, a six-inch layer of filter and bedding material, and an eight-inch-thick layer of small diameter rock for erosion protection. The consolidated tailings and contaminated materials would have sideslopes of 20 percent. The topslope would be two percent. The stabilized embankment would cover approximately 60 acres, measuring 2200 feet long in the east-west direction and 1500 feet wide in the north-south direction. The embankment would average approximately 30 feet above the surrounding terrain to the north, east, and west. A ditch would be constructed to divert surface water runoff into an existing arroyo near the embankment. The arroyos on the northeast and east sides would be armored with rock to prevent their advancement toward the stabilized pile.

The buildings and other structures associated with the former milling operations at Mexican Hat were demolished as part of Phase I site construction activities. Phase II remedial activities were to consist of consolidation of all Mexican Hat and Monument Valley contaminated materials in the disposal cell at Mexican Hat. The debris from the demolished structures was consolidated with the tailings and other contaminated materials prior to suspension of Phase II construction. In addition, the upper tailings pile and most of the windblown/waterborne contamination at Mexican Hat were stabilized on the original
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1.0 INTRODUCTION

1.1 PURPOSE

This RAP has been developed to serve a two-fold purpose. It presents the activities proposed by the DOE to accomplish long-term stabilization and control of the RRM from Monument Valley, Arizona, and Mexican Hat, Utah, at the Mexican Hat disposal site. It also serves to document the concurrence of both the Navajo Nation and the NRC in the remedial action. This agreement, upon execution by the DOE and concurrence by the Navajo Nation and the NRC, becomes Appendix B of the Cooperative Agreement.

1.2 RESPONSIBILITIES

In 1978, Congress passed Public Law 95-604, the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, expressly finding that uranium mill tailings located at inactive (and active) mill sites may pose a potential health hazard to the public. Title I to the UMTRCA identified 24 sites to be designated for remedial action. On November 9, 1979, the sites near Mexican Hat and Monument Valley were designated as two of these 24 sites.

The UMTRCA charged the EPA with the responsibility for promulgating remedial action standards for inactive mill sites. The purpose of these standards is to protect the public health and safety and the environment from radiological and nonradiological hazards associated with radioactive materials at the sites. The final standards were promulgated with an effective date of March 7, 1983.

The DOE will select and execute a plan of remedial action that will satisfy the EPA standards and other applicable laws and regulations. Under the UMTRCA, the DOE and the Navajo Nation entered into a cooperative agreement effective October 7, 1983, for remedial action at the Mexican Hat and Monument Valley sites. The DOE will fund 100 percent of allowable costs.

It is the intent of the DOE, as required by UMTRCA, to comply with EPA regulations in Subparts A through C of 40 CFR 192 in the preparation of this RAP. All remedial action planning and design considerations contained herein reflect the incorporation of this regulatory guidance. Therefore, by performing all remedial action activities in accordance with the design presented in this RAP, the DOE will meet the standards of 40 CFR 192.

All remedial actions must be selected and performed with the concurrence of the NRC. In conformance with the UMTRCA, the required NRC concurrence with the selection and performance of proposed remedial actions and the licensing of long-term surveillance and maintenance of disposal sites will be for the purpose of ensuring compliance with the standards established by the EPA. Therefore, the RAP constitutes the initial document in the licensing process.
1.3 SCOPE AND CONTENT

This document has been structured to provide a comprehensive understanding of the remedial action proposed for the Monument Valley and Mexican Hat sites. It includes specific design and construction requirements for the remedial action. Pertinent information and data are included with reference given to the supporting documents.

Section 2.0 presents the EPA standards, including a discussion of their objectives. Section 3.0 summarizes the present site characteristics and provides a definition of site-specific problems. Section 4.0 is the site design for the proposed action. Section 5.0 presents the water resources protection strategy. Section 6.0 summarizes the plan for ensuring health and safety protection for the surrounding community and the on-site workers. Section 7.0 lists the responsibilities of the project participants. Section 8.0 describes the features of the long-term surveillance and maintenance plan.

Attached as part of the RAP are appendices that describe various aspects of the remedial action in more detail.

Appendix A, Phases I and II Subcontract Completion Report (three volumes), describes the remedial activities completed at the sites (to May 1990) with supporting characterization data and calculations.

Appendix B, Specifications, Design Drawings, Calculations (five volumes), and Information for Bidders (three volumes) contains detailed information on the remedial action design.

Appendix C, Radiological Support Plan, describes the procedures used to characterize the present radiological condition of the site and the procedures to be used to control and verify the results of remedial action activities.

Appendix D, Site Characterization, includes additional information and data supporting the design of the proposed remedial action.

Appendix E, Water Resources Protection Strategy, describes how the remedial action will be in compliance with the proposed EPA groundwater standards.

Appendix F, Groundwater Hydrology Calculations, contains calculations supporting the groundwater hydrology assessment and the water resources protection strategy.

1.4 COLLATERAL DOCUMENTS

The Mexican Hat Environmental Assessment (EA) (DOE, 1987) describes existing conditions and the impacts of stabilizing the Mexican Hat contaminated materials at the Mexican Hat disposal site. The Monument Valley EA (DOE, 1988) describes the conditions at the Monument Valley site and the proposed remedial action of codisposal of the Monument Valley and Mexican Hat contaminated materials at the Mexican Hat disposal site. The Monument
Valley EA also addresses the alternatives considered, the environmental impacts at the Monument Valley site, and those impacts at the Mexican Hat site that result from the proposed action.

An additional supporting document is the Technical Approach Document (DOE, 1989a). This document describes technical approaches and procedures used in the UMTRA Project. It includes discussion of major technical areas; design considerations; surface-water hydrology and erosion control; geotechnical aspects of pile design; radiological issues (the design of the radon barrier, in particular); and protection of groundwater resources.

Copies of these documents are on file in the UMTRA Project Office in Albuquerque, New Mexico.
2.0 EPA STANDARDS

The requirements and considerations for long-term isolation and stabilization of tailings, radon control, cleanup of land and buildings, and protection of water quality have been discussed and published in the Plan for Implementing EPA Standards for UMTRA Project Sites (DOE, 1984a). That document was used as a guide in the development of the RAP and is the basis for the following discussion of the EPA standards.

2.1 GENERAL

Pursuant to the requirements of the UMTRCA, the EPA has promulgated health and environmental standards to govern cleanup, stabilization, and control of RRM at inactive uranium mill tailings sites. The promulgated standards establish requirements for long-term stability and radiation protection, and provide procedures for ensuring the protection of groundwater quality.

In developing the standards, the EPA determined that "the primary objective for control of tailings should be isolation and stabilization to prevent their misuse by man and dispersal by natural forces such as wind, rain, and flood waters," and that "a second objective should be to reduce radon emissions from tailings piles." A third objective should be "the elimination of significant exposure to gamma radiation from tailings piles" (refer to the preamble to Standards for Remedial Actions at Inactive Uranium Processing Sites, 40 CFR 192). These conclusions were based on a determination that the most significant public health risks associated with inactive tailings were posed by exposure to persons living and working in structures contaminated by relocated tailings. The EPA further concluded that the potential for contamination of groundwater and surface water should be evaluated on a site-specific basis.

The EPA standards are discussed in the following paragraphs and are summarized in Table 2.1.

2.2 LONG-TERM STABILITY

Isolation and stabilization of tailings in order to prevent misuse by man and dispersal by natural forces is the primary objective of the EPA standards. Accordingly, long-term stability was emphasized in the development and promulgation of the standards. This is consistent with the guidance provided by the legislative history of the UMTRCA, which stresses the importance of avoiding remedial actions that would be effective only for a short period of time and that would require future Congressional consideration.

The EPA standard-setting process distinguished "passive controls" (such as thick earthen covers, below-ground disposal, rock covers, and massive earth and rock dikes) from "active controls" (such as semi-permanent covers, fences, warning signs, and restrictions on land use). Active cover controls could be expected to need frequent replacement or other major repairs requiring the appropriation and expenditure of public
PART 192 - HEALTH AND ENVIRONMENTAL PROTECTION STANDARDS FOR URANIUM MILL TAILINGS

SUBPART A - Standards for the Control of Residual Radioactive Materials from Inactive Processing Sites

192.02 Standards

Control shall be designed to:

(a) Be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years, and,

(b) Provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not:

(1) Exceed an average release rate of 20 picocuries per square meter per second, or

(2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter.

SUBPART B - Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites

192.12 Standards

Remedial actions shall be conducted so as to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site:

(a) The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than:

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and

(2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

(b) In any occupied or habitable building:

(1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and

(2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour.

SUBPART C - Implementation (condensed)

192.20 Guidance for Implementation

Remedial action will be performed with the "concurrence of the Nuclear Regulatory Commission and the full participation of any state that pays part of the cost" and in consultation as appropriate with other government agencies.

192.21 Criteria for Applying Supplemental Standards

The implementing agencies may apply standards in lieu of the standards of Subparts A or B if certain circumstances exist, as defined in 192.21.

192.22 Supplemental Standards

"Federal agencies implementing Subparts A and B may in lieu thereof proceed pursuant to this section with respect to generic or individual situations meeting the eligibility requirements of 192.21."

(a) "...the implementing agencies shall select and perform remedial actions that come as close to meeting the otherwise applicable standards as is reasonable under the circumstances."

(b) "...remedial actions shall, in addition to satisfying the standards of Subparts A and B, reduce other residual radioactivity to levels that are as low as is reasonably achievable."

(c) "The implementing agencies may make general determinations concerning remedial actions under this Section that will apply to all locations with specified characteristics, or they may make a determination for a specific location. When remedial actions are proposed under this Section for a specific location, the Department of Energy shall inform any private owners and occupants of the affected location and solicit their comments. The Department of Energy shall provide any such comments to the other implementing agencies [and] shall also periodically inform the Environmental Protection Agency of both general and individual determinations under the provisions of this section."


---

TABLE 2.1
EPA STANDARDS
funds. In setting the standards, the EPA called for designs that rely primarily on passive controls.

The standard is framed as a longevity requirement that recognizes the difficulty in predicting long-term performance with a high degree of confidence. In establishing the longevity requirement, the EPA concluded that existing knowledge permits the design of control systems that have a good expectation of lasting at least 1000 years. Therefore, a design objective of 1000 years was established to be satisfied whenever reasonably achievable, but in any case, with a minimum performance period of 200 years.

The standard recognizes the need for institutional controls (e.g., custodial maintenance, monitoring, and contingency response measures). In its preamble to the standards, the EPA calls for such controls to be provided as an essential backup to the primary passive controls.

2.3 RADON EMISSIONS CONTROL

The EPA identified a reduction of radon emissions from tailings piles as the second objective in its standards for the control of tailings. In developing the standards, the EPA considered several alternative approaches and selected an emission limitation as the primary form of the standard. Radon-222 emissions from the remediated tailings piles will be less than 20 pCi/m² s (40 CFR 61 and 40 CFR 192.02(b)(1)). In addition, a concentration limit was established by the EPA as an alternative form of the standards for use in cases where the DOE determined that the alternative was appropriate.

In establishing the emission limitation for tailings piles, the EPA sought to reduce both the maximum risk to individuals living near the sites and the risk to the population as a whole. The radon standard will limit the increase in radon concentration attributable to a pile to a small increase above the background radon level near the disposal site. Both radon standards are design standards with compliance to be determined on the basis of predicted rather than measured emission rates and concentrations. The EPA states that "post-remediation monitoring will not be required to show compliance, but may serve a useful role in determining whether the anticipated performance of the control system is achieved."

In establishing the radon standard, the EPA determined that the emission limitation could be achieved by well-designed thick earthen covers, and that such control techniques would be compatible with the requirements of the EPA longevity standard.

2.4 WATER RESOURCES PROTECTION

The proposed EPA groundwater standards require characterization of the hydrogeologic regime at inactive uranium mill tailings and processing sites such as the Monument Valley and Mexican Hat sites (40 CFR 192). These regulations state that "judgments on the possible need for remedial or protective actions for groundwater aquifers should be guided by relevant considerations described in the EPA's hazardous waste management system (47
FR 32274)." The EPA standards (40 CFR 192) were published on January 5, 1983, and became effective on March 7, 1983. However, on September 3, 1985, the U.S. Tenth Circuit Court of Appeals remanded the groundwater standards, 40 CFR 192.2(a)(2)-(3). The EPA issued proposed groundwater standards on September 24, 1985.

Under the UMTRCA, the DOE must comply with the proposed standards until final standards are promulgated. The design for the codisposal of the Monument Valley and Mexican Hat contaminated materials at the Mexican Hat disposal site has been formulated to comply with the requirements of the proposed standards. Codisposal at the Mexican Hat disposal site would not preclude subsequent design enhancements at the disposal site, if needed, to achieve compliance and would not limit the selection of reasonable groundwater restoration methods that may be necessary when final standards are promulgated.

When the final EPA standards are promulgated, the DOE will reevaluate its groundwater protection plan for the Mexican Hat disposal site and undertake such action necessary to ensure that the final standards are met. The need for and extent of aquifer restoration at both the Mexican Hat and Monument Valley sites will be evaluated in a separate National Environmental Policy Act (NEPA) decision-making process.

2.5 CLEANUP OF LANDS AND BUILDINGS

The EPA evaluated the risk associated with the dispersal of tailings off the site and concluded that the principal risk to man was the exposure to radon daughter products inside buildings. The EPA therefore stated that the objective of tailings cleanup from around existing structures was to achieve an indoor radon daughter concentration (RDC) of less than 0.02 working level (WL). For open lands, the purpose of removing the contamination is to remove the potential for excessive indoor RDCs that might arise from new construction on contaminated land.

A standard of 5 picocuries per gram (pCi/g) and 15 pCi/g radium-226 (Ra-226) concentration limits for 15-centimeter (cm) surface and subsurface layers, respectively, were considered adequate to limit indoor RDCs to below 0.02 WL. Likewise, concentration limits for 15-cm surface and subsurface layers are 5 pCi/g and 15 pCi/g for Th-232. A secondary concern was to limit human exposure to gamma radiation.

The standard requires that RRM be removed from buildings exceeding 0.03 WL. In cases where levels are between 0.02 and 0.03 WL, the Federal government will have the flexibility to use measures such as sealants, filtration devices, or ventilation devices to reduce concentrations to below 0.02 WL.
3.0 SITE CHARACTERIZATION SUMMARY

This section summarizes the preconstruction conditions of the Mexican Hat and Monument Valley sites, with emphasis given to radiation, geology, and groundwater due to their importance in the remedial action design. The detailed characterizations of the Mexican Hat disposal site and Monument Valley tailings site are found in Appendix D, Site Characterization.

3.1 SITE DESCRIPTIONS

Monument Valley site

The Monument Valley tailings site is on the Navajo Reservation in Arizona, 17 road miles south of the Mexican Hat disposal site (Figure 3.1). The tailings are on the west side of Cane Valley at an elevation of approximately 4900 feet above mean sea level. The climate is arid, with an average annual precipitation of six inches. Vegetation along the sides of Cane Valley is sparse, consisting of plant species adapted to the dry environment. Vegetation in the valley bottom is somewhat more lush, especially along the ephemeral Cane Valley Wash where small springs and seeps are scattered.

The mill at the Monument Valley site was operated from 1955 to 1968 by Vanadium Corporation of America and its successor, Foote Mineral Company. All of the mill buildings and most of the milling equipment have been removed from the site. The two tailings piles, the concrete building foundations, and debris remain at the site (Figure 3.2). The two irregularly shaped tailings piles occupy approximately 28 acres in the center of the 100-acre designated site and contain 1,030,000 cy of tailings. The total amount of contaminated materials, including the tailings, soils beneath and around the tailings, and other contaminated materials, is estimated to be 1,100,000 cy.

Four Navajo residences are located within 0.25 mile of the tailings piles.

Mexican Hat site

The Mexican Hat site is approximately eight miles north of the Utah-Arizona state line and two road miles southwest of Mexican Hat, Utah. It lies within the Navajo Reservation (Figure 3.1). The area is situated in an arid region with desert terrain. Major topographic features of the area include the San Juan River to the north and Alhambra Rock to the west. The land is mainly used for livestock grazing and residences.

The 235-acre designated site (Figure 3.3) consisted of two tailings piles covering 69 acres. Several of the original mill buildings and structures and concrete pads for the former mill building and trade school building remained in place until they were demolished by the DOE during Phase I remedial action in 1987. A former mill building was decontaminated
FIGURE 3.1
LOCATIONS OF THE MONUMENT VALLEY AND MEXICAN HAT SITES
TO MEXICAN HAT, UTAH 17 MILES

NAVAJO TRIBE

NAV

AJO TRIBE

POB (POINT OF BEGINNING)

(Figure 3.2)
MONUMENT VALLEY SITE DESIGNATION

MONUMENT VALLEY SITE

BEGINNING AT A POINT WHICH IS N 50° E, 1025 FT FROM AN ARIZONA STATE PLANE COORDINATE GRID LOCATION IN THE CENTER OF THE "NEW TAILINGS PILE" AS N = 2,192,209 & E = 587,559 AND RUNNING: THENCE N 3° E, 1300 FT; THENCE S 0° W, 2541.84 FT; THENCE N 50° W, 858.61 FT; THENCE N 40° E, 1500 FT; THENCE S 50° E, 1000 FT; THENCE N 87° E, 1150 FT TO THE POINT OF BEGINNING.

CONTAINS 101 ACRES (MORE OR LESS)
FIGURE 3.3
MEXICAN HAT SITE DESIGNATION

and is used as the Halchita Health Clinic. An elementary school and the housing area are approximately 0.3 and 0.6 mile southwest of the former mill site, respectively.

The mill was constructed and operated from 1957 to 1963 by Texas-Zinc Minerals Corporation. The plant was then sold to Atlas Corporation and operated until 1965. During operation, approximately 2.2 million tons of ore were processed to produce 5700 tons of uranium oxide (\(U_3O_8\)) concentrate.

Phase I remedial action was completed in 1987. It consisted primarily of demolishing the remaining mill buildings (except the sheet metal shop), constructing a vehicle decontamination pad and retention basins, and fencing the site.

Partial Phase II remedial action was completed in 1990. It included the placement of demolition debris in the disposal cell (the lower tailings pile), removal and disposal of upper tailings and windblown and waterborne materials in the disposal cell, and incorporation of permanent drainage features.

3.2 RADIATION

This section summarizes the characterization of radioactive materials at the Monument Valley and Mexican Hat uranium mill tailings sites. The details of the characterization investigations and of the calculations leading to the summary values for the Mexican Hat disposal site are contained in Appendix D, Site Characterization.

Radiological data from the vicinity of the sites have been collected in numerous investigations since 1961. The radiological data summarized here describe background radiological conditions, increases of radiation above background due to the tailings, the extent and degree of the contamination on the site and in its vicinity, and the volume and average radioactivity of the contaminated materials.

3.2.1 Background radiation--Monument Valley and Mexican Hat sites

Background radioactivity data provide a reference to which levels of contamination can be compared in assessing the extent of contaminated areas requiring cleanup and the magnitude of radioactive releases from the site. Radioactive elements occur naturally throughout the earth's air, water, and soil. The concentration of these elements varies greatly throughout the United States. Background soil radioactivity averaged 1.0 pCi/g at the Monument Valley site and 1.1 pCi/g at the Mexican Hat site for Ra-226.

The average background gamma radiation exposure rate from both terrestrial and cosmic sources measured at three feet above the ground is 11 microroentgens per hour (\(\mu\text{R/hr}\)) at both the Monument Valley and Mexican Hat sites. Quarterly average measurements for background radon-222 (Rn-222) were made at various locations around both sites for an entire year using integrating film-type radon detectors. The annual average background Rn-222 concentrations at the Monument Valley and Mexican Hat sites were 0.37 and 0.61 picocuries per liter (pCi/l), respectively.
3.2.2 Preconstruction conditions

The radioactive materials at the Monument Valley and Mexican Hat sites cause the ambient radiation to be above natural background. Measurements of on-site gamma exposure rates, airborne particulates, and radon concentrations in air are summarized below. These are important in estimating the radiological hazard produced by the site.

Monument Valley site

- The Ra-226 contamination at the Monument Valley site is of relatively low activity (50 to 60 pCi/g) but is spread extensively across the entire area. Due to the low activity, it is estimated that only 218 curies per year (Ci/yr) of radon are released from all contaminated materials on the site.

- Most of the contaminated materials are very coarse, ranging in size from about a millimeter in diameter to small rocks. This is a result of the upgrading process used, in which the fines were extracted and transported off the site for further processing. Thus, there is very little windblown contamination. Although the material is coarse, airborne particulate measurements on and near the tailings showed thorium-230 (Th-230) levels up to 56 percent of the levels allowed for continuous exposure by the public (4 E-14 mCi/mL of soluble thorium) (DOE Order 5400.5).

- The on-site radon concentration was estimated from six radon monitoring locations around the site perimeter. The annual average concentration at these six locations was 1.6 pCi/l.

Mexican Hat site

- Off-site gamma exposure rate measurements indicate exposure rates elevated above background as much as 2500 feet downwind (east-northeast).

- Contamination has been transported by site runoff down many of the deep arroyos leading off the site. Radionuclides were also dumped into a lateral arroyo during processing.

- Airborne particulates were measured on and near the tailings piles. The maximum permissible concentrations (MPC) for unrestricted releases were not exceeded for Th-230. The 11-day averages reached 17 percent of the MPC for Th-230.

- The on-site radon concentration was estimated from four monitoring locations around the site perimeter. The annual average concentration for the four locations was 7.8 pCi/l.
3.2.3 Contaminant distribution

Monument Valley site

The contaminated areas of the Monument Valley site and its vicinity are shown in the excavation plan in calculation No. 19-332-01-00, pages 26-27, "Site Excavation and Average Contamination," in Appendix B (Volume II). The origin and extent of the contamination are summarized below.

The uranium mill tailings at the Monument Valley site are in six distinct areas, with other substantially smaller volumes scattered around the periphery. The largest volume (about 769,000 cy) is in and beneath the lower pile and pond area. The lower pile is a cone about 1000 feet in diameter and about 60 feet high. An additional 259,000 cy are in and beneath the upper pile and heap leach pads. The material beneath the tailings in the lower pile and leached ore in the heap leach pads is contaminated. However, the contamination extends only about a foot deeper than the physical interface between the tailings and the ground.

The processing of the original material (fines separation) was performed on the ridge leading from the Monument No. 2 Mine, immediately west of the heap leach pad. The coarse sand fraction was stored at the site of the heap leach pads. The ore storage and mill yard area was built up from the original topography with pit run rock, and is referred to as Area E in subsequent discussions.

In October 1964, equipment was installed for batch leaching of the sand fraction. The area of the installation (Area C) was built up and leveled using pit run rock and is located between the upper pile and the lower pile. As a result, approximately 23,700 and 14,000 cy of Areas E and C, respectively, are mildly contaminated. The batch leach operation processed the coarse sand fraction from the area of the heap leach pads. The resulting tailings were used to form what now is the lower pile. A small remnant of the original old pile of coarse fraction material comprises Area D. In addition, remnants of the coarse fraction material lie along the eastern edge of Area E over the steep drop-off to the heap leach pads. After processing virtually all of the coarse fraction in the batch leach plants, the depression beneath the old pile was filled with very coarse low grade ore. This material was heap leached in place and has remained undisturbed.

A small area northeast of the heap leach pads and immediately north of the batch leach area is also contaminated with what appears to be windblown tailings. However, the windblown area north of the lower pile extends only several hundred feet. This indicates that the materials northeast of the heap leach pads are remnant tailings left over from the batch leach operation, and not windblown.

Other areas near the site have small amounts of contamination. About 20 sites north of the former ore storage and mill yard area contain piles (10-foot radius and one foot deep) of rubble that are slightly contaminated. These appear to be associated with housing
(temporary structures) for the mine and mill workers. In addition, roads were constructed for the mine and mill operations throughout the processing site area and from the mine site on the ridge to the west. The roads were built with a brown siltstone overlying a gray-green mudstone that appears to have been taken from the Monument No. 2 mine. The mudstone averages about 50 pCi/g of Ra-226. Pit run rock from the mine was also used for fill where the roads cross the many arroyos around the site.

Table 3.1 summarizes the volumes and Ra-226 concentrations of all major areas on the site. The total volume of contaminated material is about 1,083,000 cy (Appendix B, Calculation 19-332-01-00).

Table 3.1 Summary of volumes and radium concentration of contaminated materials at the Monument Valley site

<table>
<thead>
<tr>
<th>Area description</th>
<th>Contaminated volume (cy)</th>
<th>Average Ra-226 concentration (pCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower pile</td>
<td>759,964</td>
<td>46.7</td>
</tr>
<tr>
<td>Evaporation pond</td>
<td>9,000</td>
<td>219.6</td>
</tr>
<tr>
<td>Heap leach pads (upper pile)</td>
<td>258,936</td>
<td>51.2</td>
</tr>
<tr>
<td>Area E (ore storage) and miscellaneous area</td>
<td>32,922</td>
<td>66.0</td>
</tr>
<tr>
<td>Area C (batch leach yard)</td>
<td>14,036</td>
<td>38.3</td>
</tr>
<tr>
<td>Area D (old pile remnant)</td>
<td>1,406</td>
<td>40.0</td>
</tr>
<tr>
<td>Rubble piles</td>
<td>4,129</td>
<td>67.8</td>
</tr>
<tr>
<td>Roads</td>
<td>3,000</td>
<td>37.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,083,393</strong></td>
<td><strong>49.7</strong></td>
</tr>
</tbody>
</table>

aVolume-weighted average.

Mexican Hat site

The site is in a wash area that drains toward the north into the San Juan River, approximately 250 feet lower in elevation. To the south and east, the site is bounded by a near-vertical ridge about 100 feet high. The site is cut by numerous dry washes that are 20 to 40 feet deep and up to 100 feet wide. Before the start of Phase II construction, the uranium mill tailings at the Mexican Hat site were in two discrete piles. The lower of the two tailings ponds was constructed by damming one of these washes. As the tailings filled in, the dam height was increased using tailings as the embankment material.
The upper and lower tailings piles were uncovered and averaged Ra-226 contents of 624 and 763 pCi/g, respectively. It was originally estimated that the upper pile contained 883,010 cy and the lower pile contained 1,623,000 cy of tailings. The average depths of these two piles were 21.5 feet (upper pile) and 23.6 feet (lower pile). Maximum depth of the upper pile was 39.8 feet and of the lower pile, 56.1 feet. There was a total of 597 Ci in the upper pile and 1421 Ci in the lower pile.

The material beneath the tailings piles consists of a thin layer of about 1.5 feet of original soil material underlain by Halgaito Formation bedrock. This entire soil layer is contaminated above the EPA standards of 15 pCi/g Ra-226. The average depths from the physical interface to the 15 pCi/g interface (bedrock) were 1.8 and 1.6 feet for the upper and lower piles, respectively.

Other sources of contaminated material on the site include the mill yard, ore storage area, a backfilled trench leading off the site to the north, and areas of windblown and waterborne contamination. All of these represent less than 10 percent of the volume of the tailings piles themselves. Table 3.2 summarizes the volumes and Ra-226 concentrations of all major areas on the site. The estimated volume of contaminated materials at the Mexican Hat site is 2,772,500 cy. The values in Table 3.2 were obtained from Calculations 9-226-03-00, 9-226-02-01, 9-239-05-02, Appendix A, Volume II.

A single exposure rate measurement was obtained from the center of the Health Clinic—Building 8. The reading was near background levels of 13 microR/hr. All other buildings have been demolished except the sheet metal shop, which will be decontaminated and left intact.

<table>
<thead>
<tr>
<th>Area description</th>
<th>Contaminated volume (cy)</th>
<th>Average Ra-226 concentration (pCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper pile</td>
<td>883,000</td>
<td>624</td>
</tr>
<tr>
<td>Lower pile</td>
<td>1,623,000</td>
<td>763</td>
</tr>
<tr>
<td>Windblown/waterborne</td>
<td>266,500</td>
<td>59</td>
</tr>
<tr>
<td>Total</td>
<td>2,772,500</td>
<td>650*</td>
</tr>
</tbody>
</table>

*Volume-weighted average.
3.3 GEOLOGY, GEOMORPHOLOGY, AND SEISMICITY

3.3.1 Introduction

Detailed investigations of geologic, geomorphic, and seismic conditions at the Monument Valley and Mexican Hat sites were conducted by the DOE. The purpose of the investigations was to obtain site characterization data and identify potential geologic hazards that could affect long-term site stability. Subsequent engineering studies such as the analyses of hydrologic and liquefaction hazards relied on the data obtained in these investigations. The findings of these investigations for the Mexican Hat disposal site are discussed in detail in Section D.4 of Appendix D, Site Characterization.

The scope of work performed included the following:

- Compilation and analysis of previous geologic literature and maps.
- Review of historical seismic data.
- Review of site-specific geologic data, including logs of exploratory boreholes advanced in the site area.
- Photogeologic interpretation of existing LANDSAT and conventional aerial photographs.
- Low-sun-angle aerial reconnaissance of the site region.
- Ground reconnaissance and mapping.

3.3.2 Geologic setting

Monument Valley site

The Monument Valley site is located in the northern part of the Navajo section of the Colorado Plateau physiographic province (Hunt, 1967) (Figure 3.4). This area is actually the eroded crest of a large north-south-trending anticline, the Monument Uplift (also referred to as the Monument Upwarp). Over most of the region surrounding Monument Valley, relatively resistant Mesozoic rocks are exposed at the surface. However, within Monument Valley, erosion has breached these resistant units and carved the underlying less-resistant Permian units into a wide array of mesas, buttes, spires, and pinnacles (Stokes, 1973). Many of these monuments seem to have been preserved because underlying rocks have been protected from erosion by a resistant caprock, formed by the Triassic Shinarump Conglomerate Member of the Chinle Formation. The Shinarump is the major source of the uranium-vanadium deposits in the site region, and is also the major unit underlying the existing tailings piles.
National Parks and Monuments

1. Dinosaur Nat. Mon.
2. Black Canyon of the Gunnison Nat. Mon.
3. Colorado Nat. Mon.
5. Canyonlands Nat. Park
6. Natural Bridges Nat. Mon.
8. Mesa Verde Nat. Park
9. Aztec Ruins Nat. Mon.
10. Chaco Canyon Nat. Mon.
   (Betatakin and Kiet Seel)
13. Rainbow Bridge Nat. Mon.
15. Bryce Canyon Nat. Park
17. Zion Nat. Park
18. Grand Canyon Nat. Park
20. Walnut Canyon Nat. Mon.
22. Montezuma Castle Nat. Mon.
23. Tuzigoot Nat. Mon.

Escarps at South End of High Plateaus

pc Pink Cliffs
wc White Cliffs
vc Vermillion Cliffs

Other Prominent Features

wf Waterpocket Fold
er Elk Ridge
cr Comb Ridge
mv Monument Valley
ag Agathla Peak
sr Shiprock
cb Cabezon Peak

REF: HUNT, 1967

FIGURE 3.4
PHYSIOGRAPHIC MAP OF THE COLORADO PLATEAU IN THE REGION OF THE MONUMENT VALLEY AND MEXICAN HAT SITES
Bedrock in the site region consists predominantly of marine to continental sediments ranging in age from Late Paleozoic to Jurassic (Haynes and Hackman, 1978; Hackman and Wyant, 1973; Haynes et al., 1972; O'Sullivan and Beikman, 1963; Witkind and Thaden, 1963; Witkind, 1956) (Figure 3.5). Minor intrusives of Tertiary to Quaternary age are also present. Evaporite deposits are not known to occur in significant amounts in the strata underlying the site. The bedrock units are overlain by unconsolidated materials of Quaternary age, chiefly eolian and alluvial in origin.

In 1951 and 1952, the U.S. Geological Survey carried out a program of geologic mapping and uranium investigations in Apache and Navajo Counties, Arizona. These studies included detailed mapping of the area of the Monument No. 2 mine, which also encompasses the area of the Monument Valley tailings site. Results of these studies were published as bulletins in the U.S. Geological Survey (Witkind and Thaden, 1963; Witkind, 1956) and served as the primary source of published geologic data for this study.

A diagram of the position of the tailings relative to bedrock and surficial units is shown in Figure 3.6. The tailings are distributed in two separate areas, referred to as the upper and lower tailings piles for this study (not shown separately on Figure 3.6). The upper tailings pile is located within a small intermittent wash that drains northeastward into Cane Valley Wash. It is underlain partly by bedrock and partly by unconsolidated alluvium and eolian sand. The exposed bedrock is primarily the Shinarump Conglomerate Member of the Triassic Chinle Formation. Outcrops of the Triassic Moenkopi Formation and the underlying Hoskinnini Tongue of the Permian Cutler Formation, which underlies the Chinle, are not exposed near the piles. However, published maps (Witkind and Thaden, 1963; Witkind, 1956) indicate that they may occur at the original ground surface beneath the upper tailings pile. The lower tailings pile, located just east of the upper pile, lies on eastward-dipping beds of the Shinarump and dune sand that overlies the Monitor Butte Member of the Chinle formation in Cane Valley Wash. The sand dune (as encountered in exploratory boreholes advanced on the site) consists of uncemented, fine- to medium-grained sand with occasional lenses of fine gravel. Its thickness appears to vary from about 20 to 30 feet along the eastern edge of the pile. This material is evidently saturated at shallow depths, possibly to within about three meters of the original ground surface beneath the new tailings pile.

There are no major faults in the site region. Small-scale normal and reverse faults, having displacements of only a few inches or feet, occur most commonly within the Monitor Butte Member of the Chinle Formation, and to a lesser extent in the Moenkopi and Summerville Formations. All exposed formations are cut by joints. The dominant joint sets range from N25°W to N65°W; from north to N15°E; and almost due east. All sets are vertical or nearly vertical.
<table>
<thead>
<tr>
<th>AGE</th>
<th>SYSTEM</th>
<th>ROCK UNIT</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>MIOCENE-</td>
<td>MORRISON FORMATION</td>
</tr>
<tr>
<td></td>
<td>JURASSIC</td>
<td>BLUFF SANDSTONE</td>
</tr>
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<td></td>
<td></td>
<td>SUMMERVILLE FORMATION</td>
</tr>
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<td></td>
<td></td>
<td>CURTIS FORMATION</td>
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<td></td>
<td></td>
<td>ENTRADA SANDSTONE</td>
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<td>CARMEL FORMATION</td>
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<td>NAVAJO SANDSTONE</td>
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<td></td>
<td>TRIASSIC</td>
<td>CHINLE FORMATION</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SHINARUMP MEMBER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MOENKOPI FORMATION</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HOSKINNINI MEMBER</td>
</tr>
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<td></td>
<td>PERMIAN</td>
<td>DECHELY SANDSTONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ORGAN ROCK SHALE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CUTLER FORMATION</td>
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<td>CEDAR MESA SANDSTONE</td>
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<td>HALGAITO SHALE MEMBER</td>
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<td>PENNSYLVIANIAN</td>
<td>HONAKER TRAIL FORMATION</td>
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<td>PINKERTON TRAIL FORMATION</td>
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<tr>
<td></td>
<td></td>
<td>MOLAS FORMATION</td>
</tr>
</tbody>
</table>

MODIFIED FROM WOODWARD-CLYDE CONSULTANTS, 1982

FIGURE 3.5
GENERALIZED STRATIGRAPHIC COLUMN
AT THE MONUMENT VALLEY AND MEXICAN HAT SITES

-21-
FIGURE 3.6
GENERALIZED EAST–WEST STRATIGRAPHIC CROSS SECTION OF THE MONUMENT VALLEY SITE
Mexican Hat site

The Mexican Hat site is in southeastern Utah, within the Navajo Uplands subdivision of the Colorado Plateau physiographic province (Figure 3.4). A portion of the area of investigation is within the adjacent Monument Valley subdivision of the Arizona-Utah region of the plateau. The Monument Valley region is characterized by steep-walled mesas, buttes, and spires rising abruptly from a nearly featureless, stripped erosional surface. Physiographic features prevalent in the Navajo Uplands area include terraced mesas and "slickrock" surfaces cut by deep, steep-walled canyons containing perennial and ephemeral streams. Extensive portions of the mesas are covered with thin sand sheets and dune fields of Quaternary to Holocene age.

Tectonic and erosional processes have exposed strata of Late Paleozoic and Early Mesozoic age throughout most of the study area (Figure 3.5). Early Paleozoic sedimentary rocks lie at depth beneath the site and outcrop to the west in Monument Valley and far to the southeast in Canyon de Chelly. South of the Mexican Hat site area, in the Black Mesa region, abundant exposures of Cretaceous sedimentary strata occur. Pennsylvanian and Permian sedimentary strata outcrop at the tailings site.

Bedrock beneath the Mexican Hat tailings pile consists of the Halgaito Shale member of the Permian Cutler Group and the Pennsylvanian Hermosa Group (Figure 3.7). The sedimentary strata consist of marine and continental limestones, sandstones, siltstones, and shales. Beds are tilted to the east at about six to eight degrees. Thin, sporadic eolian sands occur as surface deposits in the Mexican Hat site area. Minor deposits of fluvial terrace gravels occur along the San Juan River about 1.9 kilometers (km) (1.2 miles) to the north.

Faulting is rare in the Mexican Hat area. The few mapped faults have offsets of a few inches to a few feet, and none are known to offset strata of Quaternary age. Thirty-one faults and fault trace zones examined within a 65-km radius of the site were determined to be non-capable.

Major structural features of the study region include the Monument Upwarp west of the site, the Comb Ridge monocline east of the site, and numerous associated anticlines and synclines. The tailings site is on the western limb of a syncline subordinate to the Monument Upwarp. The dominant structural features of the region probably formed during the Early Tertiary Period. Minimal tectonic activity has occurred since the end of the Eocene Epoch. The latest episodes of volcanic activity occurred during the Pliocene Epoch. There is no evidence of any potential for renewal of volcanic activity in the site area during the 1000-year design life. Economic mineral resources are not present in significant quantities in the site area. Therefore, no impacts on the long-term stability of the remedial action are expected to result from the exploitation of mineral resources in the area.
FIGURE 3.7
GENERALIZED STRATIGRAPHIC SECTION
FOR THE MEXICAN HAT SITE REGION
3.3.3 Geomorphology

Monument Valley site

Wind erosion has scattered moderate amounts of fine-grained tailings around the area of the upper tailings pile and mill site, and along the north and east sides of the lower tailings pile.

Fluvial erosion of the upper tailings pile is occurring within a deeply incised channel passing through the pile and exiting to the northeast. Removal of the tailings during remedial action will eliminate further erosion hazards from this channel. Lateral channel migration and headward gully erosion within Cane Valley Wash south and east of the lower tailings pile present potential erosion hazards to that pile. Channel migration could shift the bed of Cane Valley Wash to a position adjacent to the tailings pile base, with a stream bed depth of up to 12 feet lower than the current elevation of the tailings pile edge. As with the upper pile, removal of the tailings during remedial action will eliminate further erosion hazards to the existing lower pile.

Mexican Hat site

Wind erosion and ephemeral stream channel erosion present the greatest geomorphic hazards to the Mexican Hat tailings site. The prevailing westward winds have removed fine-grained tailings from the existing pile. A fluvial erosion hazard is present from the two ephemeral stream channels near the north and east edges of the tailings pile. Lateral and headward erosion are possible in each of these channels. No hazards appear to be present from slope instability conditions or subsidence.

3.3.4 Seismicity

Monument Valley site

The Monument Valley site is in the central portion of the Colorado Plateau, a stable intracontinental subplate characterized by a thick cover of relatively flat-lying sedimentary rock of Phanerozoic age overlying a complex Precambrian igneous and metamorphic core (Figure 3.8). The central, stable portion of the plateau exhibits characteristics of cratonic areas, while the margins of the subplate exhibit crustal structure similar to more highly active bordering provinces. The plateau is bordered on the east, south, and west by the extensional, block-faulted regime of the Rio Grande Rift and Basin and Range Provinces. Since Late Tertiary time, the plateau has been experiencing gradual uplift at an average rate of about two millimeters per year (Gable and Hatton, 1980). This uplift is regional in character and produces relatively little internal deformation.
FIGURE 3.8
STRUCTURE CONTOUR MAP OF THE COLORADO PLATEAU SHOWING THE MAJOR BASINS AND UPLIFTS AND LOCATION OF THE MONUMENT VALLEY SITE

(AFTER HUNT, 1956)
A map of historical and instrumental seismicity of the southwestern United States is shown in Figure 3.9. The site is within a region that has been characterized by widely separated, low magnitude seismic events during historical times. Geologic evidence for Quaternary fault activity within the Colorado Plateau is rare.

The potential for on-site fault rupture at the Monument Valley site is statistically nonexistent, based on the geologic investigations conducted for this study. There is virtually no hazard at the site from reservoir-induced seismicity or seismically induced landslides. No evidence exists of any potential for volcanic activity in the site area.

**Mexican Hat site**

The 200-km radius seismotectonic study area around the Mexican Hat site includes portions of the Colorado Plateau; Basin and Range; Rio Grande Rift; and Intermountain Seismic Zone seismotectonic provinces (Figure 3.10). The Colorado Plateau contains the Mexican Hat site and is the least tectonically active of the provinces. The largest historical earthquake in the Colorado Plateau occurred north of Flagstaff, Arizona, in 1912, and had a recorded magnitude of 5.5 to 5.75 on the Richter scale. The vast majority of Colorado Plateau interior events are microseismic. Outside of the San Francisco volcanic field, east of Flagstaff, neotectonic fault evidence is lacking or scanty. No historical earthquakes with recorded epicenters are reported within a 65-km radius of the Mexican Hat site. No capable faults have been identified within this same area.

A floating earthquake of magnitude 6.2 is considered to be the design earthquake for the Mexican Hat site. This event, as defined, could occur anywhere within the Colorado Plateau physiographic and seismotectonic province.

The UMTRA Project seismic evaluations assume that the floating earthquake will occur at a radial distance of 15 km from the site. It is estimated that such an event would produce an on-site, freefield, peak horizontal acceleration of 0.21 g. Existing north-to-northwest-trending faults located 200 to 300 km west of the site could host future earthquakes. These faults lie along the eastern edge of the historically active Intermountain Seismic Zone of southern Utah. The current northeast-southwest extensional regime appears to control regional seismic focus orientations of these fault systems. Activity on these faults would result in site accelerations less than that produced by the floating earthquake.

The potential for on-site fault rupture at the Mexican Hat site is statistically nonexistent based on the geologic investigations conducted for the study. There is virtually no hazard at the site from reservoir-induced seismicity or seismically induced landslides.
FIGURE 3.9
MAP OF HISTORICAL AND INSTRUMENTALLY DETECTED EARTHQUAKE EPICENTERS OF THE SOUTHWESTERN UNITED STATES EPICENTRAL COMPILATION LIMITED TO EVENTS OF MAGNITUDE ≥4 AND/OR INTENSITY (MMI) ≥V.
FIGURE 3.10
MAJOR SEISMIC ZONES OF THE BASIN AND RANGE - COLORADO PLATEAU PROVINCES

REF: WONG ET AL., 1982
MEXICAN HAT, UTAH, AND MONUMENT VALLEY, ARIZONA SITE LOCATIONS
3.4 GEOTECHNICAL

3.4.1 Subsurface investigations

Monument Valley site

The site and nearby surrounding soils were characterized by drilling 49 boreholes and excavating 31 test pits (Appendix B, Information for Bidders, Volume III). Of the 49 boreholes, seven were completed for geotechnical soil data gathering in the natural soils, 18 holes were logged through soil and rock without gathering geotechnical soil data, six holes were logged solely through rock, and 18 holes were logged through tailings and into the underlying soils.

Six of the seven geotechnical boreholes (601 through 606) are east of the lower tailings pile. The seventh hole (607) is north of the upper tailings pile area. Continuous standard penetration tests (SPT) were conducted on each hole for the first eight feet. The holes were then drilled, without sampling, to a depth of 10 feet. SPTs were typically resumed at 10 to 14 feet, after which drilling without sampling was used to drill to the total depth of the hole. In borings 604 through 607, SPTs were also conducted over sporadic intervals at depths greater than 20 feet. No undisturbed samples were collected from these borings. All seven of the geotechnical boreholes were completed by the DOE.

All 18 holes that were logged through natural soil and rock, without gathering geotechnical data, were drilled by the DOE as part of the groundwater investigation. All except three of these holes are north of the lower pile area. The three exceptions are borings 651, 654, and 658. These holes are northeast, east, and southeast of the lower pile, respectively. These holes give complete geologic descriptions of the soils encountered, in addition to detailed descriptions of the bedrock at each location.

The six holes drilled and logged into bedrock were not logged through soil. These holes were all drilled by the DOE as part of the groundwater investigation of the area. The holes are to the west, south, and east of the lower pile. These logs start at the bedrock-soil interface, and are therefore helpful only as data pertaining to the depth of the foundation soils.

Bendix (BFEC, 1985) drilled and logged holes through the new tailings pile to characterize the tailings and to determine the depth of contamination.

All 31 of the test pits were excavated by the DOE. Of these 31 test pits, six were excavated in tailings, one in the evaporation pond area, and 24 in areas that had been, but were no longer being, considered for borrow material. Five of the six test pits excavated in tailings were excavated in a grid pattern on the lower tailings pile. Test pits MONO1-062 through MONO1-065 were along the upper portion of the sloping, cone-shaped pile, while MONO1-066 was at the eastern edge of the pile. Test pit MONO1-061 was in the center of
the heap leach pile. The test pits excavated in the interior portion of the pile ranged from nine to 12 feet deep, while the perimeter test pit (MON01-062) encountered natural soil at five feet. Test pit MON01-061, on the heap leach pile, was excavated to 15 feet without reaching natural soil.

The single test pit in the evaporation pond area is MON01-067. This test pit was excavated to seven feet and encountered natural soil at approximately three feet.

Mexican Hat site

To characterize subsurface materials in and near the Mexican Hat site, 192 borings and five test pits were completed. Of the total, 157 borings and five test pits were completed on the tailings pile. The borings were done at various times by the DOE; Ford, Bacon & Davis Utah Inc. (FBDU); Mountain States Research and Development (MSRD); and the University of Colorado (UC). Details of these investigations are presented in the following sections.

Locations of the DOE piezocone soundings, boreholes, coreholes, and test pits are shown in Figures 3.11 and 3.12. A summary of the boring, piezocone sounding, and test pit numbers and depths is presented, as well as the respective logs, in Appendix D, Site Characterization. Locations of 1979 UC borings are shown in Figure 3.13. Locations of the MSRD/Colorado State University (CSU) borings and the MSRD piezometer locations are shown in Figure 3.14. A summary of the boring numbers and depths for both the MSRD and MSRD/CSU boreholes, as well as copies of the boring logs and well completion records, are in Appendix D, Addendum D4.

Earlier subsurface investigations at the Mexican Hat site

Prior to March 1976, FBDU, in conjunction with Oak Ridge National Laboratory (ORNL), advanced 19 borings on or near the tailings pile at Mexican Hat (FBDU, 1977). These borings were done primarily to characterize the radiological properties of the tailings. Geotechnical logs of these borings, if they exist, are not available.

In March 1979, UC, under a grant from the DOE/EPA, bored three shallow unlogged holes by hand at Mexican Hat in a preliminary investigation of the geotechnical properties of a number of uranium mill tailings sites in the United States (Heuze and Dessenberger, 1979).

In late 1981, MSRD initiated a drilling program that was completed in early 1982 (MSRD, 1982). This drilling program included about 125 borings. The soils in these borings were visually classified and logged as well as continuously sampled using both split barrel and Shelby tube-type samplers. Two of the borings were completed as monitoring wells. The main purpose of this program was to obtain assay samples to determine the economic feasibility of processing the tailings. Little or no geotechnical data, beyond the
FIGURE 3.11
PIEZOCONE SOUNding, Borehole, Test Pit and Cross Section Locations At the Mexican Hat Site

LEGEND
- PIEZOCONE SOUNding ONLy
- PIEZOCONE SOUNding AND Borehole At Same Location
- Borehole ONly
- Test Pit and Piezocene And/or Borehole At Same Location
- Test Pit Only
FIGURE 3.12
EAST–WEST CROSS SECTION B–B' THROUGH THE UPPER AND LOWER TAILINGS PILE
AT THE MEXICAN HAT SITE
FIGURE 3.13
UC BORING LOCATIONS AT THE MEXICAN HAT SITE
FIGURE 3.14
CSU BOREHOLE AND PIEZOMETER LOCATIONS
AT THE MEXICAN HAT SITE
logs themselves, were obtained. A minor aspect of this program was to obtain samples for geotechnical testing by CSU; however, these samples were never used in a testing program.

Other subsurface geotechnical investigations at the Mexican Hat site

Forty piezocone soundings were completed on a 200-foot-square grid over the tailings pile area in order to aid in the placement of borings in the tailings, to determine which intervals should be sampled during drilling operations, and to characterize the tailings (Figure 3.11) (Appendix D, Addendum D6).

Soil samples were obtained for testing by means of both geotechnical borings and test pits. Fourteen shallow borings and two deep borings were completed in the tailings pile in late 1984 and early 1985. The shallow holes were advanced using a six-inch hollow-stem auger. The two deep boreholes were augered to bedrock and cored below the soil/bedrock interface. All boreholes were continuously logged in order to note the changes in the visual soil or rock classification with depth within the tailings and foundation. To aid in this visual classification and provide samples for laboratory testing, disturbed and undisturbed soil samples were obtained through the use of SPT, the split-barrel or Dames and Moore (D&M) sampler, and the Shelby-tube sampler (Appendix D, Addendum D4).

In addition to the on-pile borings, 16 shallow borings and 11 deep borings were done in the vicinity of the tailings pile in order to characterize the soils and rock in the foundation. The shallow borings were advanced with a four-inch hollow-stem auger. The borings were logged and auger cuttings were sampled. The deep borings were augered to bedrock without sampling, then continued through the bedrock using rotary coring with continuous core sampling and logging. Most of these deeper borings were completed as groundwater monitoring wells (Appendix D, Addendum D4).

Four test pits were dug on the tailings pile and one near it (in windblown tailings) in order to obtain bulk samples for laboratory testing. The test pits were dug to depths ranging from 0.5 to 7.5 feet using a backhoe, and were sampled and continuously logged to note soil changes with depth (Appendix D, Addendum D4).

3.4.2 Foundation materials

Monument Valley site

The soils underlying the Monument Valley site generally consist of fine-grained, unconsolidated dune sand with isolated zones of fine-grained silty clay and clayey sand alluvium. These materials have been derived from the existing sedimentary sandstone, siltstone, and, to a lesser degree, shale bedrock formations that outcrop in the immediate area of the site and within Cane Valley.
Sandstone bedrock composed of the Shinarump Member of the Chinle Formation outcrops along the west side of Cane Valley and directly underlies the former mill-site and portions of the upper, older tailings pile. The heap leach pad, which is in a small wash at the base of a 20-foot-high Shinarump Sandstone cliff near the upper tailings pile, is composed of approximately 14 feet of coarse tailings materials. Under these tailings, the small wash is filled with dune sand deposits more than 80 feet deep. The lower tailings pile lies entirely atop the loose dune sand, which becomes progressively thicker eastward from the site. Approximately 500 feet southeast of the lower tailings pile, boring 603 was drilled 55 feet through loose dune sand without encountering bedrock.

The Cane Valley alluvium is primarily thin to thick layers and lenses of sand and sandy silt, with considerably lesser amounts of clay and gravel, deposited throughout the axis of Cane Valley and along drainages perpendicular to the valley axis. No material properties are required for these deposits, as they do not underlie any of the areas of importance to this study.

**Mexican Hat site**

The foundation materials underlying the tailings at the Mexican Hat site consist of siltstones and sandstones overlain by zero to five feet of soil derived primarily from the bedrock material.

The soils vary from silty fine sands to slightly sandy gravels. Most of the borings indicate a soil thickness in the range of zero to one foot under and near the tailings pile. In the washes, the soil is generally a gravelly alluvium between three and five feet thick. For the purpose of this investigation, the alluvium is assumed to have properties similar to the weaker tailings that directly overlie the alluvial soils.

The bedrock under the site consists of siltstones and sandstones of the Halgaito Shale Formation of the Cutler group (Permian Age). At the Mexican Hat site, this formation is composed chiefly of red-brown fine sandy siltstones that occasionally grade to silty fine sandstones. Occasional layers of limestone are greater than 15 feet thick; however, they are typically less than one foot thick. The intact rock is generally soft to hard; however, there are numerous zones that have close, nearly horizontal fractures. These fractures are often unweathered and unfilled or healed. There are a few zones where the wall rock is weathered to produce low-plasticity clay zones up to three feet thick. These clayey zones appear to be discontinuous and are found at depths greater than 75 feet below the tailings-rock interface. They should not affect the long-term stability of the finalized tailings pile.

A more detailed description of the foundation materials and their geotechnical properties can be found in Appendix D, Site Characterization.
3.4.3 Tailings

Monument Valley site

Materials forming tailings can generally be put into one of three categories: sand, sand-slime mixture, and slime. The limits of gradation for these materials are defined as zero to 30 percent passing the No. 200 sieve to be classified as a sand; 30 to 70 percent passing to be classified as a sand-slime mixture; and 70 to 100 percent passing to be classified as a slime. The processing practices at the Monument Valley site yielded tailings characterized as homogeneous fine- to medium-grained sands with little or no slimes fraction. The top three feet of the evaporation pond area contain the only slimes at the site, with a medium to coarse brown sand fill underlying these slimes to at least seven feet, which was the depth of the investigation. No sand-slime mixtures are present on the site. Since the tailings piles are composed entirely of sand tailings, no detailed cross sections of the piles are presented.

Mexican Hat site

Boring logs and field observation indicate that starter dikes or dams were built over and/or extended from naturally formed rock dikes using coarse tailings. Mill run tailings were hydraulically deposited behind the dikes via spigots that were probably moved periodically. Thus, the resulting distribution of tailings in the pile varies greatly with horizontal location and depth. The generalized cross sections in Figures 3.12 and 3.15 through 3.17 were constructed using borehole and piezocone data. Locations of these sections are found on Figure 3.11. These indicate that, as the tailings embankment filled, the retaining embankments were made up of fairly uniform sand tailings. With increasing horizontal distance from the embankment, the tailings generally tend to grade to slime. However, as is indicated in the individual boring and piezocone logs (see Section D.5 of Appendix D, Tailings Characteristics), this generalization does not hold true in detail. The assumed variation in spigot location and the temporal variations in the particle size and parent material makeup of the tailings over the life of the milling operation resulted in an extremely complicated stratified deposit that may vary from a silty sand to a silt to a clay over a relatively small change in depth or lateral location. This means that a standard-size sample that may classify as sand, sand-slime, or slime in bulk may actually be a complex layered soil in situ. This is especially true of the sand-slimes.

Material types

Generally, the sands in the Mexican Hat tailings were found to be loose to medium-dense, slightly moist to very moist, nonplastic silty sands (SM). The sand-slimes can be described as very loose to loose, moist to very moist, nonplastic silty sands (SM) or soft to medium consistency, moist to wet, nonplastic to low-plasticity sandy silts (ML). The slimes are generally best described as moist to
FIGURE 3.15
NORTH-SOUTH CROSS SECTION A-A' THROUGH THE LOWER TAILINGS PILE
AT THE MEXICAN HAT SITE
FIGURE 3.16
EAST-WEST CROSS SECTION C-C' THROUGH THE LOWER TAILINGS PILE
AT THE MEXICAN HAT SITE
FIGURE 3.17
NORTH-SOUTH CROSS SECTION D–D' THROUGH THE UPPER TAILINGS PILE
AT THE MEXICAN HAT SITE
saturated, very soft to medium consistency, low to medium plasticity clays (CL). They tend to be overconsolidated in the lower pile and softer, tending toward normally consolidated in the upper pile. Section D.5 of Appendix D, Site Characterization, provides detailed engineering properties of the tailings.

3.4.4 Borrow sites

The source for the radon cover material will be the RB-4 and RB-7 borrow sites (Figure 3.18); the borrow sites are along the bottom of an arroyo on Navajo Nation land approximately five miles south of the Mexican Hat site. There are only limited quantities of the borrow material, which is a silty sand.

Two borrow sites have been identified as potential sources for rock cover material between Bluff and Mexican Hat, Utah. Large rock for the erosion protection may be taken from the Sugarloaf quarry and the smaller rock and bedding may be taken from the Bluff quarry (Figure 3.19). The subcontractor may elect to obtain bedding and riprap materials from other borrow sources, provided the size and quality requirements are met.

3.5 GROUNDWATER

Monument Valley site

A summary of the hydrogeologic characterization at the Monument Valley site is presented in this section. A detailed hydrogeologic and groundwater quality characterization is presented in Appendix D, Site Characterization.

The major hydrostratigraphic units underlying the Monument Valley tailings site, in descending order, are alluvium and dune sand, the Shinarump Member of the Chinle Formation, the Moenkopi Formation, and the DeChelly Sandstone. The alluvium and dune sand are fine-grained, unconsolidated deposits more than 80 feet thick in the center of Cane Valley. The thickness of these deposits decreases toward the valley edges, where it is absent. The Shinarump Member outcrops west of the tailings site, dips to the east, and underlies the dune sand and alluvium below the lower tailings pile. The Shinarump Member consists of lenticular cross-bedded units of sandstone, conglomerate, and mudstone, and ranges from 25 to 90 feet thick in the site vicinity. The Moenkopi Formation underlies the Shinarump Member and consists of shaley siltstone and sandstone. The Moenkopi Formation is 50 to 60 feet thick in most of the site area; however, only about 20 feet of the Moenkopi Formation was encountered beneath the upper tailings pile. The DeChelly Sandstone is a cross-bedded, fine-grained sandstone and is approximately 550 feet thick below the site (Witkind and Thaden, 1963).

Groundwater within the alluvial aquifer is unconfined. Depths to groundwater range from a few feet near Cane Valley Wash to slightly more than 10 feet below the lower tailings pile. This unconfined groundwater is recharged by occasional flows in Cane Valley Wash and to a minor extent by
FIGURE 3.18
LOCATIONS OF RADON BARRIER BORROW SITES
MEXICAN HAT/MONUMENT VALLEY REMEDIAL ACTION
FIGURE 3.19
LOCATIONS OF THE ROCK BORROW SITES
MEXICAN HAT/MONUMENT VALLEY REMEDIAL ACTION
infiltration of precipitation. Alluvial groundwater in the site vicinity flows to the north under an average hydraulic gradient of 0.011, and discharges as underflow or to seeps in northern Cane Valley. Using the range of hydraulic conductivities of 0.3 to 19 feet/day (ft/day) (1.1 x 10⁻⁴ to 6.7 x 10⁻³ centimeters per second, or cm/s) and an assumed effective porosity of 0.25, the linear groundwater velocity is five to 300 ft/year.

Groundwater within the Shinarump Member is confined, probably by the mudstones found within this unit. This confined groundwater flows northward from recharge areas in the south, under an average hydraulic gradient of 0.01, and probably discharges to the alluvium in northern Cane Valley. Using the range of hydraulic conductivities of 0.4 to eight ft/day (1.4 x 10⁻⁴ to 2.8 x 10⁻³ cm/s) and an assumed effective porosity of 0.10, the linear groundwater velocity is 15 to 290 ft/year.

Groundwater within the DeChelly Sandstone is confined by the overlying Moenkopi Formation. This confined groundwater flows northward from recharge areas in the south, under an average hydraulic gradient of 0.01, and discharges to areas north of Cane Valley. Using the range of hydraulic conductivities of 0.02 to three ft/day (7.1 x 10⁻⁶ to 1.1 x 10⁻³ cm/s) and an assumed effective porosity of 0.10, the linear groundwater velocity is 0.8 to 120 ft/year.

An upward, vertical hydraulic gradient exists between the Shinarump Member and the overlying alluvium and dune sand, and between the DeChelly Sandstone and the overlying units. Wells completed within the DeChelly Sandstone flow at the surface in the area of the Monument Valley tailings site.

Background water quality in the alluvium is generally good, with no median or mean observed concentrations exceeding the proposed EPA maximum concentration limits (MCL). However, maximum observed background concentrations of molybdenum have exceeded the MCLs. Background groundwater in the Shinarump aquifer underlying the Monument Valley site has produced concentrations or activities of net gross alpha and molybdenum that exceeded MCLs prior to 1990. Only radium-226 and -228 activities exceeded the MCL in one background monitor well in 1990. Background groundwater in the DeChelly Sandstone aquifer has produced concentrations of molybdenum that exceeded MCLs prior to 1990. However, no MCLs were exceeded in the background monitor wells sampled in 1990 or in 1991.

The tailings at the Monument Valley site are much more sandy and contain fewer slimes than those at Mexican Hat. During the early years of operation, this site was used to physically concentrate the slime fraction, which contained the majority of the uranium. This fine-grained fraction was then shipped to other mills for refining. In later years, low-grade ores and the stockpiled sand fraction were heap leached. This resulted in contaminated materials that produce an acidic, oxidizing leachate. Hazardous constituents in the tailings pore fluids with mean concentrations or activities that exceed the proposed EPA MCLs are molybdenum, nitrate, and radium-226. Concentrations of these hazardous constituents in tailings pore fluids at the Monument Valley processing site are slightly less than those determined as representative of tailings pore fluid at Mexican Hat. No Appendix IX organic hazardous constituents related to uranium milling processes were observed above detection levels at the Monument Valley site.
Maximum observed concentrations of cadmium, chromium, molybdenum, nitrate, and selenium, and activities of net gross alpha, and radium-226 and -228 have exceeded the proposed EPA MCLs or background levels in the alluvium. The presence of these constituents, except cadmium and selenium, is related to uranium tailings processing activities. Cadmium and selenium did not exceed laboratory method detection limits in tailings pore water. There is no statistically significant evidence of groundwater contamination above the MCLs from chromium, molybdenum, net gross alpha, radium-226 and -228 in downgradient groundwater. However, there is statistical evidence that nitrate exceeds the MCL in groundwater from monitor wells 606 and 655.

Nitrate in the alluvium forms a plume that extends approximately 3000 feet downgradient (north) of the site. Within the plume, nitrate concentrations range from a high of over 1000 mg/l in the central portion to below the MCL on the fringe. Even though the plume has moved a distance downgradient, there has been no substantial plume migration laterally to the east.

In downgradient groundwater from the Shinarump Conglomerate, maximum observed concentrations or activities of molybdenum, net gross alpha, and radium-226 and -228 equaled or exceeded MCLs. However, there is no statistically significant evidence for groundwater contamination above the MCLs for these constituents in Shinarump groundwater.

In the DeChelly Sandstone downgradient groundwater, maximum observed concentrations or activities of molybdenum, net gross alpha, and uranium equaled or exceeded MCLs. However, there is no statistically significant evidence of groundwater contamination above the MCLs from chromium, net gross alpha, and uranium in downgradient DeChelly Sandstone groundwater. Median concentrations of molybdenum did exceed the MCL in the past in monitor wells 664 and 668 and in former production well 625. However, more recent sampling rounds showed molybdenum less than detection in monitor well 668 and well 625.

An upward hydraulic gradient between the DeChelly Sandstone and the overlying formations has served to prevent significant downward movement of contaminated groundwater from the alluvium. However, during the period of milling operations when groundwater was produced from the DeChelly, the upward hydraulic gradient could have been reversed locally in the areas of maximum withdrawal. This temporary downward gradient from the alluvium to the DeChelly could have caused contaminated groundwater to flow to the DeChelly, which would account for the elevated molybdenum concentrations in some wells in the past.

Groundwater from the alluvium in the vicinity of the Monument Valley tailings site is used as a source of drinking water by residents upgradient and far downgradient of the tailings site. Groundwater from the DeChelly Sandstone is withdrawn for domestic use from one well (625) northeast of the tailings piles. A domestic well survey was conducted in 1992. This survey did not locate residences or domestic wells in the path of the alluvial nitrate plume.
Mexican Hat site

A summary of hydrogeological characterization at the Mexican Hat site is presented in this section. A detailed hydrogeologic characterization is included in Section D.7 of Appendix D, Site Characterization. All hydrogeological calculations are included in Appendix F, Groundwater Hydrology Calculations.

The Mexican Hat disposal site is underlain by the Halgaito Shale Formation of the Cutler Group. This formation is composed of a varied sequence of interbedded, very fine-grained silty sandstone and siltstone beds (O'Sullivan, 1965) and ranges from 50 to 180 feet thick in the site vicinity. The Halgaito Shale Formation is underlain by the Honaker Trail Formation of the Hermosa Group, which consists of more than 300 feet of interbedded siltstones, limestones, shales, and sandstones (FBDU, 1981a; Wengerd, 1973).

Perched water and unconfined groundwater related to uranium milling operations occur at depths ranging from 35 to 60 feet beneath the Mexican Hat tailings in the Halgaito Shale Formation. Water-bearing fracture density within the Halgaito Shale Formation decreases with depth, so that the lower section of the formation becomes an aquitard that locally confines naturally recharged groundwater in the underlying Honaker Trail Formation. Recharge to the perched groundwater within the Halgaito Shale Formation occurs from tailings seepage and minor amounts of infiltration from precipitation and flows in the arroyos within the vicinity of the tailings. Perched water and groundwater in the area of saturation within the Halgaito Shale Formation may spread laterally along lower hydraulic conductivity layers that dip regionally to the east and southeast. The average hydraulic conductivity of the Halgaito Shale Formation is 0.20 ft/day (7 x 10^{-4} cm/s).

Naturally occurring groundwater within the Honaker Trail Formation flows under an average hydraulic gradient of 0.02 to the north. The Honaker Trail Formation is recharged by groundwater underflow and may contribute some discharge to springs and seeps in Gypsum Creek or discharges as groundwater underflow from the site. The average hydraulic conductivity of the Honaker Trail Formation is 0.07 ft/day (2.5 x 10^{-5} cm/s). Assuming an effective porosity of 0.10 to 0.20, the average linear groundwater velocity is 0.01 ft/day (3 x 10^{-3} meter per day, or m/day).

The perched water in an area of saturation within the Halgaito Shale Formation is present primarily as the result of milling activities. Consequently, there is little or no native groundwater and, thus, background water quality cannot be defined for the Halgaito Shale Formation. Water derived from tailings seepage, sampled in monitor wells completed within the Halgaito Shale Formation, has a relatively high total dissolved solids (TDS) content, with TDS concentrations ranging from 1670 mg/l to 6670 mg/l. Maximum concentrations of chromium, molybdenum, uranium, and nitrate, and net gross alpha activities, exceed the proposed EPA MCLs. After the tailings have been reconfigured into a disposal cell and covered with a low permeability radon/infiltration barrier, the tailings seepage to the Halgaito Shale Formation will become negligible.
Maximum observed concentrations or activities of four hazardous constituents equaled or exceeded proposed EPA MCLs in the Honaker Trail Formation groundwater. These constituents include chromium, net gross alpha, radium-226 and -228, and uranium. The lower end of the 98 percent confidence interval of the mean for concentrations of these constituents by monitor well was compared with the MCL. According to "Statistical Analyses of Groundwater Monitoring Data at RCRA Facilities - Interim Final Guidance" (EPA, 1989), if the lower end of the confidence interval of the mean exceeds the MCLs, there is statistical evidence of an exceedance of the MCLs. The lower end of the 98 percent confidence interval of the mean concentrations of these constituents do not exceed MCLs in the Honaker Trail Formation.

No contamination of the Honaker Trail Formation has occurred from the Mexican Hat site, because an upward hydraulic gradient between the Honaker Trail Formation and the Halgaito Shale Formation prevents downward migration of tailings seepage into the Honaker Trail Formation. Furthermore, the Halgaito Shale Formation hydraulic conductivity decreases with depth due to a decrease in fracture density with depth.

Codisposal of the Monument Valley and Mexican Hat tailings at the Mexican Hat site will produce an embankment containing 3.8 million cy of material. This material is a combination of sands and slimes typical of an acid leach process. The Monument Valley tailings contain less fine-grained material and are much sandier than the Mexican Hat tailings. The pH of the tailings is relatively low (3.0 to 4.5) and the redox potential is oxidizing. The Monument Valley and Mexican Hat tailings contain hazardous constituents, including Appendix IX inorganic constituents derived from the uranium milling processes. Concentrations or activities of hazardous constituents in the codisposed tailings that exceed the proposed EPA MCLs are arsenic, cadmium, chromium, molybdenum, nitrate, uranium, radium-226 and -228, selenium, silver, and net gross alpha. No Appendix IX organic hazardous constituents related to uranium processing activities were above detection limits in the tailings at the Mexican Hat site. A screening of Appendix IX inorganic constituents identified antimony, cobalt, copper, fluoride, nickel, vanadium, and zinc as hazardous constituents or elements contained in hazardous constituent compounds above detection limits.

Water discharges from seeps in the North Arroyo exhibit maximum observed concentrations or activities of molybdenum, net gross alpha, nitrate, and uranium above MCLs. Discharges from these seeps are from water related to milling operations. Water discharges from Gypsum Creek seep GS-3 (254) may also have some contribution from milling operations-related water based on major cation/anion chemistry, elevated nitrate concentrations, and elevated uranium concentrations. Discharges from seeps in Gypsum Creek are primarily from the upward movement of native groundwater from either the Halgaito Shale Formation or the Honaker Trail Formation. However, in addition to seep GS-3, four Gypsum Creek seeps exhibit concentrations of uranium elevated generally an order of magnitude above background. These seeps appear to have a component of discharge derived from milling operations-related water. These seeps have very low flow rates of 0.5 gallons per minute (gpm) or less, where measured, and discharge into arroyos which are dry most of the time. A risk assessment has been conducted to address the potential risk of these seeps to humans, wildlife, and domestic animals (Appendix E, Section E.3.3).
assessment concluded that no adverse non-carcinogenic health effects are expected for the above groups.

Groundwater in the Halgaito Shale Formation and the Honaker Trail Formation in the vicinity of the Mexican Hat site is not used as a source of drinking water or for other domestic beneficial purposes. Groundwater has not been developed in the Halgaito Shale Formation because of the limited areal extent of saturation in the site vicinity and the low hydraulic conductivity of the formation, which results in low yields to wells. Groundwater within the Honaker Trail formation has not been developed because of poor water quality (hydrocarbons and hydrogen sulfide gas). Alternative supplies of good water quality are readily available from the San Juan River, which supplies all the water used in the area.

3.6 SURFACE WATER.

Monument Valley site

Surface-water features in the vicinity of the Monument Valley tailings site include Cane Valley Wash and several small ephemeral drainages. The tailings site is approximately 10 feet higher in elevation and 1300 feet west of Cane Valley Wash (Figure 3.20). The San Juan River, 15 air miles north of the site, is the only perennial stream in the area.

Cane Valley Wash has a drainage area of 90 square miles at the tailings site. The east and south arroyos drain a 650-acre watershed on Yazzie Mesa south of the tailings site. The arroyos join 300 feet east of the lower tailings pile to course northward into the wash. Another arroyo (the west arroyo) drains a 1120-acre watershed and courses northeastward to the upper tailings pile and heap leach pad area. The middle arroyo drains a 60-acre watershed and flows into the south arroyo (Figure 3.20).

Runoff from the 1180-acre west and middle arroyo watersheds passes through the site. After passing through the upper tailings pile area, drainage from the west arroyo spreads runoff to a flat area north of the lower tailings pile. Drainage from the middle arroyo flows into the south arroyo, and eventually empties into Cane Valley Wash. It is doubtful that surface water flows over the upper pile area during most runoff events. Rather, runoff probably infiltrates into the soil because of the permeability of the eolian deposits. The middle arroyo flows northeast toward the lower tailings pile boundary and then turns to the east at a sandstone bedrock outcrop approximately 750 feet south of the pile boundary. The channel is incised eight feet below the alluvial surface and 10 feet below the sloping edge of the bedrock outcrop. During normal runoff events, water is probably contained in the channel.

Runoff from the site area generally flows northeast towards Cane Valley Wash. However, there are some low-lying areas and depressions in the west arroyo plus a few areas east and west of the lower tailings pile (particularly in the old evaporation pond area) where ponding may occur during precipitation events.
FIGURE 3.20
REGIONAL SURFACE WATER CHARACTERISTICS AT THE MONUMENT VALLEY SITE
There are no water quality data for any of the surface water features associated with the Monument Valley tailings site. The surface water features at the site are arroyos and only contain water during runoff events.

There are no known uses for any of the surface waters in the ephemeral arroyos and Cane Valley Wash, since flow in these drainages occurs only after excessive precipitation.

The existing tailings site could be affected by a flood in the west, east, or south arroyo. Water from a Probable Maximum Precipitation (PMP) event could overtop the channel banks in the east arroyo and reach the boundary of the lower tailings pile. A PMP is defined as the maximum precipitation that could occur from the most severe combination of meteorological conditions that are reasonably possible in a region. Areas indicative of periodic standing water and possible flooding exist between the east arroyo and the eastern edge of the lower tailings pile.

**Mexican Hat site**

The San Juan River, the major surface-water feature in the Mexican Hat area, is approximately one air mile north of and 240 feet below the Mexican Hat tailings site (Figure 3.21). This perennial river flows generally west-northwest along a deeply incised, meandering course. Over a 69-year period of record at Mexican Hat, the river had a mean flow of approximately 2500 cubic feet per second (cfs), for an average annual discharge of approximately 1,800,000 acre-feet. The recorded peak flow in the river at Mexican Hat is 52,800 cfs (USGS, 1985).

The U.S. Geological Survey (USGS) operates a continuous water-quality sampling station on the San Juan River downstream of the tailings site. Data from this station (USGS, 1985) and from sampling performed by Geochemistry and Environmental Chemistry Research (GECR, 1982) show that the river water meets National Primary Drinking Water Standards and exceeds Secondary Drinking Water Standards only for iron and pH. Additional sampling of the river water by the EPA (1973) and the DOE has shown that radiological contaminant levels in the water are below the standards and that the tailings piles have had no effect on the quality of the water. Water samples are withdrawn from the river at a treatment facility on the south bank of the river near the crossing of U.S. Highway 163 (Figure 3.21).

Several well-entrenched arroyos drain a watershed of approximately 500 acres south of the tailings site into the San Juan River. The largest and closest of these arroyos is Gypsum Creek (Figure 3.21), which is approximately 0.5 air mile northeast of, and approximately 100 feet below, the tailings site. There are no flow records for any of the arroyos because flows occur only after excessive precipitation.

At the tailings site, a small area around the Halchita sewage lagoons drains into an ephemeral arroyo north of the lagoons (Figure 3.21). The rest of the tailings site and a 370-acre watershed around Halchita drain into an ephemeral arroyo north of the tailings pile (North Arroyo). These two well-entrenched arroyos course north and northeast, respectively, to the San Juan River. Several smaller arroyos tributary to the northeast-
coursing arroyo intersect the lower tailings pile on the north and east sides. There are no flow records for any of the ephemeral arroyos at the tailings site.

Seven seeps have been identified within Gypsum Creek east of the tailings site, and three seeps occur in the North Arroyo north of the tailings pile. These surface discharges of groundwater are low (less than approximately one-half gpm each, where measured) and discharge into the arroyos which are dry most of the time. These seeps are discussed in more detail in Section D.7 of Appendix D, Site Characterization.

There are no water-quality data for the ephemeral drainages at and around the tailings site, and there are no known uses of the ephemeral flows in the drainages.
4.1 INTRODUCTION

This section describes the design for codisposal of the Mexican Hat and Monument Valley tailings at the former uranium processing site near Mexican Hat. The data are intended to provide sufficient detail to evaluate the feasibility and effectiveness of the proposed design. The proposed design is predicted to meet the requirements of 40 CFR 192. The proposed design details are presented in Appendix B, Specifications and Drawings.

4.2 SUMMARY OF PROPOSED REMEDIAL ACTION

The Mexican Hat site consisted of two tailings piles; stockpiled rubble from the Phase I demolition of several of the original mill buildings, structures, and concrete pad of the mill buildings; and windblown areas. The Monument Valley site consists of two tailings piles; heap leach pads; an evaporation pond; two ore storage and mill yard areas; rubble piles; and windblown areas. Prior to Phase II suspension, the lower pile at Mexican Hat was shaped, and approximately 1,210,000 cy of Mexican Hat tailings from the upper pile and off-pile contaminated materials were placed on top of the lower pile.

Approximately 1,093,300 cy of contaminated material from the Monument Valley site will be transported to the Mexican Hat site and will be placed as the upper ten feet of the Mexican Hat tailings embankment. The top of the resulting stabilized pile will slope to the northwest. The final embankment will cover an area of approximately 60 acres (Figure 4.1). Construction completed to date is described in Appendix A, Phases I and II Subcontract Completion Report.

The cover placed on the stabilized pile will consist of a radon and infiltration barrier and erosion protection layer. The radon barrier will consist of selected uncontaminated material obtained from designated borrow areas. The entire radon barrier will be amended with bentonite. The erosion protection materials will consist of a layer of bedding material topped by a layer of rock riprap. The radon barrier borrow materials will be obtained from the RB-4 and RB-7 borrow sites (see Figure 3.18) and the erosion protection borrow materials are expected to be obtained from the Bluff and Sugarloaf sites (see Figure 3.19). During remedial action, all disturbed areas will be graded to promote drainage and appropriate measures taken to resist erosion.

4.3 DESIGN FEATURES

The principal feature of the remedial action is the stabilization of the Monument Valley and Mexican Hat contaminated materials at the Mexican Hat disposal site.
FIGURE 4.1
FINAL EMBANKMENT, MEXICAN HAT SITE
The following activities, including the construction of temporary facilities, have been completed during Phase I and Phase II construction at Mexican Hat and Monument Valley:

- Construction of temporary wastewater retention basins and dikes to prevent release of contaminants, a decontamination pad to wash equipment, and site security fencing.

- Demolition and stockpiling of on-site surface and subsurface structures and utilities at Mexican Hat.

- Reshaping of the lower tailings pile at Mexican Hat.

- Excavation, transportation, and placement of the remaining contaminated materials at the Mexican Hat site on the lower tailings pile. These materials include the upper tailings pile, portions of the lower pile, off-pile contaminated materials, and demolished material stockpiled at the former mill site.

- Site preparation at the Monument Valley site, including construction of temporary wastewater retention basin and dikes, and decontamination facilities.

- Upgrade of the haul road between the Monument Valley and Mexican Hat sites (Indian Service Road 6440) and construction of a bypass at Halchita.

- Construction of permanent ditches, aprons, and a diversion ditch to collect and carry surface runoff away from the stabilized embankment at Mexican Hat.

Major construction activities to be performed at both Mexican Hat and Monument Valley for completion of remedial action construction would be as follows:

- Excavation and transportation of tailings and contaminated materials from the Monument Valley site to be placed on the tailings embankment at the Mexican Hat site.

- Cleanup of remaining windblown and waterborne contaminated materials at Mexican Hat.

- Installation of the final cover over the tailings at Mexican Hat to inhibit water infiltration, radon emanation, and erosion.

### 4.4 PERMANENT DESIGN FEATURES

#### 4.4.1 Layout

The tailings embankment has been designed to contain an additional 2,300,000 cy of contaminated material on top of the lower tailings pile and will cover approximately 60 acres, resulting in a pile containing a total of 3.8 million cy of contaminated...
material. The lower tailings pile at Mexican Hat has been stabilized in place. Tailings from the upper pile and contaminated materials from windblown areas were then placed over the lower tailings pile. Contaminated material from Monument Valley will be placed as the top layer of the stabilized pile. Lastly, the radon and infiltration barrier, erosion protection, and permanent drainage structures will be constructed (Figure 4.2).

4.4.2 Decontamination and restoration

Contaminated materials from the wastewater retention basins, dikes, and decontamination facilities at both sites will be placed in the tailings embankment. Access to the completed tailings embankment will be restricted while the remainder of the Mexican Hat site and all of the Monument Valley site are graded to promote drainage, stabilized from erosion, then released for any use consistent with land use controls. Backfill at the Monument Valley site will be minimal.

4.4.3 Embankment construction

The configuration of the embankment at the Mexican Hat site will minimize the handling of tailings and contaminated materials and use the natural topography of the Mexican Hat processing site to reduce the potential impacts from erosion. The design also incorporates existing sand dikes at the Mexican Hat site to minimize earthwork (see Figure 4.2).

Relocated tailings and contaminated materials will be placed and compacted on the tailings embankment. Contaminated organic materials will be evenly distributed throughout the embankment so that no more than five percent organic material by volume is present in any area of the pile. Demolition debris will be placed in the lower portion of the embankment and surrounded with compacted tailings. Site preparation details and embankment compaction criteria are presented in the Project Site Design Criteria (DOE, 1984b).

The embankment top will have a two percent grade to promote drainage. The sideslopes will be limited to a 20 percent grade to create a stable slope.

4.4.4 Cover construction

The radon emanation rate will be controlled through a design that meets EPA standards by placing and compacting less-contaminated materials in the upper portion of the pile, then placing a radon barrier consisting of 24 inches of compacted, uncontaminated soil over the embankment. The radon barrier will be composed of a silty sand from a nearby borrow source amended with 10 percent bentonite. The radon barrier will be protected on all sides by a rock riprap layer designed to prevent erosion due to wind or rain runoff from the PMP.
FIGURE 4.2
TYPICAL CROSS SECTION OF THE DISPOSAL CELL
MEXICAN HAT SITE
The erosion protection layer consists of an eight-inch-thick layer of 1.7-inch (or larger) mean diameter rock on the top of the embankment, and a one-foot-thick layer of 4.4-inch (or larger) mean diameter rock on the sideslopes and the aprons of the embankment. A graded bedding layer will be placed beneath the rock layer to protect the fine-grained soils of the radon barrier from erosion by interstitial flow, protect the radon barrier during placement of the riprap layer, and function as a drain that sheds water laterally off the pile.

4.4.5 Site drainage

The Mexican Hat site will be graded and permanent drainage features constructed to protect the embankment from erosion. Drainage ditches will direct runoff around the embankment and into the arroyos. Runoff from the western watershed and west sideslopes of the embankment will be intercepted by the west ditch. Runoff from the east sideslope of the embankment will flow eastward and northeastward as sheet flow and will be released across the rock-covered aprons. Runoff from the top of the embankment will flow to the north and northwest as sheet flow, and down the north side of the embankment across the rock-covered apron into the north ditch. The ditches will be sized and protected with riprap sufficient to carry the runoff from a one-hour PMP, except for the north ditch and diversion ditch. Both of these ditches are expected to be excavated within the upper resistant layer of sandstone, which would not require additional erosion protection. The north ditch will have engineered riprap in an excavated keyway at its outfall into the North Arroyo to prevent headcutting.

In addition, a 1.25-foot-thick layer of 6.9-inch (or larger) mean diameter rock will be placed in the diversion ditch and gully 1; a 1.5-foot-thick layer of 4.4-inch (or larger) mean diameter rock will be placed in gully 2; a 1.5-foot-thick layer of 6.9-inch (or larger) mean diameter rock will be placed in gully 3; and a 13-inch-thick layer of 6.9-inch (or larger) mean diameter rock will be placed in the west ditch (Appendix B, Subcontract Drawings).

4.4.6 Groundwater protection

The disposal cell design will comply with the site-specific groundwater protection standards in 40 CFR 192.02(a)(3) as determined from an assessment of the hydrogeologic characteristics of the site, design analysis of the disposal unit, and performance assessment of the disposal site (NRC, 1988). The disposal cell is designed to meet the proposed EPA MCLs or background water quality, whichever is higher, in the Honaker Trail Formation (the uppermost aquifer). A detailed analysis of the groundwater protection strategy at the Mexican Hat site is provided in Appendix E, Water Resources Protection Strategy. Seepage of tailings fluids into the Honaker Trail Formation is precluded by the upward gradient between
the Honaker Trail Formation and the Halgaito Shale Formation and by a decrease in hydraulic conductivity with depth in the Halgaito Shale Formation in the area of the tailings pile. This upward hydraulic gradient is artesian in the vicinity of the tailings disposal cell. Because of the advantageous hydrogeologic setting, the surface remedial action will comply with the proposed EPA groundwater protection standards.

Groundwater contamination from milling-related tailings seepage forms an area of saturation in the Halgaito Shale Formation beneath and downgradient of the Mexican Hat site. This groundwater has migrated laterally east and southeast of the pile and is the major component of seep discharge for seeps in the North Arroyo and for seep GS-3 (254) in Gypsum Creek. This contaminated groundwater also contributes to flow of four other seeps in Gypsum Creek. However, based on the water quality type of major cations and anions, the major component of flow is from upward movement of natural groundwater. The North Arroyo seeps are located within the site boundary. A risk assessment has been performed (JEG, 1990) that addresses the health and environmental risk from the Gypsum Creek seeps located beyond the designated site boundary (Appendix E, Section E.3.3). This study concluded that there is negligible risk to human health and the environment associated with the Gypsum Creek seeps, given the relative inaccessibility of Gypsum Creek.

4.4.7 Flood protection

The stabilized site will be protected from the Probable Maximum Flood (PMF) generated from the PMP on the upland watershed and on the embankment. Permanent drainage ditches will be constructed to carry the PMF runoff.

4.5 CONSTRUCTION FEATURES

4.5.1 Layout

Construction will occur at the Mexican Hat and Monument Valley processing sites, the borrow sites, and along the haul roads. During Phase I construction at the Mexican Hat site, an access control area was built east of U.S. Highway 163 and northeast of the former Mexican Hat processing site, and an equipment decontamination pad was constructed adjacent to the vehicle access gate. During Phase II construction, a second decontamination pad was constructed in the southwest corner of the Mexican Hat site. Access control, decontamination, and drainage facilities were constructed at the Monument Valley site. Contaminated wastewater at both sites will be directed to retention basins constructed on the sites. Fences will isolate the staging areas at both sites.
4.5.2 Site access

The sites are fenced to control traffic entering and leaving the sites and prevent unauthorized traffic from entering the controlled areas.

4.5.3 Staging area facilities

During construction, temporary facilities will be provided for construction workers and supervisory, engineering, administrative, security, and radiation monitoring personnel at both the Monument Valley and Mexican Hat sites. The facilities will consist of office space, emergency showers, change facilities, and portable toilets.

4.5.4 Utilities

At the Mexican Hat site, existing power lines, a six-inch water line, and a sanitary sewer line leading to the health clinic will be maintained during remedial action. All other site utilities will be removed or abandoned during construction. No utilities are present at the Monument Valley site.

4.5.5 Drainage, erosion control, and wastewater retention basins

During remedial action, all drainage from contaminated areas will be diverted to wastewater retention basins or catchment areas. Temporary drainage ditches and dikes are designed to carry the peak flow from the one-hour 10-year storm event. Runoff outside the affected areas will be diverted away from contaminated areas.

Existing catchment areas will be enlarged to control peak flows into the heap leach pad area at the Monument Valley site. In addition, dikes will be used to divert runoff to the retention basin at this site. This will eliminate the need for ditches being constructed in the rock terrain and becoming a permanent feature after construction.

The retention basins are designed to retain the runoff from a 24-hour 10-year storm as well as the wash water from decontamination operations. The retention basins at each site have sufficient capacity to hold all sediment inflow over the life of the project without sediment removal. The emergency overflow of the basins is designed to safely discharge the one-hour 25-year storm peak inflow.

4.5.6 Equipment decontamination pad

Decontamination pads with a concrete sump will be provided to wash contaminated equipment and trucks at both processing sites, thereby preventing contaminated materials from being removed from the controlled area.
4.5.7 Dust control

Dust generated by excavation, earth movement, vehicle use, temporary material stockpiling, and similar activities will be controlled and minimized by the use of water and water-based surfactants sprayed from hoses or trucks. Dust suppression water for use on contaminated areas will be supplied by the wastewater retention basins, supplemented as necessary with uncontaminated water. Contaminated water will be used only in the contaminated areas. Spraying schedules will be determined hourly. The frequency of spraying will increase when combinations of low soil moisture and windy conditions are encountered.

4.5.8 Borrow areas

Borrow areas for radon barrier and erosion protection materials have been identified. Radon barrier material will be obtained from the RB-4 and RB-7 borrow sites, which are approximately five road miles south of the Mexican Hat processing site. The haul route will be Indian Service Road 6440 and a bypass already constructed to the east of Halchita connecting the service road to the Mexican Hat processing site.

Rock for erosion protection and bedding material is expected to be quarried at the Bluff and Sugarloaf quarries. The subcontractor may elect to obtain bedding and riprap materials from other borrow sources, provided the size and quality requirements are met. Material for restoring the Mexican Hat processing site will be excavated from uncontaminated areas at the site. Restoration material for the Monument Valley site will be excavated from a borrow area adjacent to the site.

4.5.9 Compaction

All contaminated materials, except the top three feet of the tailings, will be compacted to 90 percent of Standard Proctor density. The top three feet of tailings will be compacted to 95 percent of Standard Proctor density. The radon barrier will be placed wet of optimum moisture content and compacted to 100 percent of Standard Proctor density. No materials (tailings or cover) will be placed during freezing conditions. Uncontaminated material used as fill for site restoration will be compacted to 90 percent of Standard Proctor density.

4.5.10 Construction sequence

Work completed during Mexican Hat Phase I construction included demolition of the remaining mill buildings (except the sheet metal shop and the health clinic) and the construction of the wastewater retention basin, dikes, temporary construction ditches,
the decontamination pad, security system, and staging and access control areas.

Initial Phase II construction primarily consisted of stabilization of the pile in place and relocation of the Mexican Hat upper pile and windblown materials to the disposal cell (lower pile).

The Phase II subcontract includes the completion of all remedial action at the Mexican Hat site and the Monument Valley site. The work at the Mexican Hat site will include the following: (Ref. Completion of Phase I and II Subcontracts, Revision I)

- Disposal of stockpiled debris.
- Disposal of all off-pile contaminated materials.
- Construction of radon barrier and infiltration cover.
- Construction of all permanent drainage features.
- Removal of all temporary facilities.
- Site restoration.

On May 31, 1989, the Monument Valley portion of the work was added to the Phase II subcontract. The Monument Valley work will include the following:

- Construction of temporary facilities.
- Disposal of rubble.
- Excavation, hauling, and disposal of tailings and other contaminated materials in the Mexican Hat disposal cell.
- Removal of temporary facilities.
- Site restoration.

4.5.11 Construction performance summary

The total embankment settlement expected to occur at the Mexican Hat disposal cell ranges from 0 to 2.7 feet (Calculation 9-420-01). The total settlement is greatest in the central portion of the embankment in the vicinity of piezocone soundings HAT01-231 and HAT01-232. The differential settlement is greatest at the southeast corner of the embankment. The differential settlement of the embankment is not expected to cause any flow concentration or adversely affect the stability of erosion protection material on the embankment.
The cover cracking potential is assumed to be the greatest when the differential settlement is the greatest. The maximum horizontal tensile strain, $\varepsilon_{\text{max}}$, of the radon barrier material at this section is 0.04 percent (Calculation 9-420-02). The estimated failure tensile strain of the radon barrier is at least 0.05 percent.

The factors of safety for slope stability are shown in Calculation 19-349-03-01. The required factors of safety for each condition are as follows:

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<th>Condition</th>
<th>Required factors of safety</th>
<th>Actual factors of safety</th>
</tr>
</thead>
<tbody>
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<td>1.9</td>
</tr>
<tr>
<td>Short-term seismic</td>
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<td>1.2</td>
</tr>
<tr>
<td>Long-term static</td>
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<td>3.0</td>
</tr>
<tr>
<td>Long-term seismic</td>
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<td>1.1</td>
</tr>
</tbody>
</table>

4.6 SCHEDULE

Mexican Hat Phase I work was completed in October 1987, and Phase II construction stopped in May 1990. Completion of the remedial action will require approximately 28 months.

4.7 REPROCESSING ASSESSMENT

The feasibility of reprocessing the Mexican Hat tailings to recover residual uranium, vanadium, and molybdenum was evaluated (MSRD, 1982). This analysis indicated that the 1981 market price of these materials would need to triple before reprocessing would become economically feasible.

The feasibility of reprocessing the Monument Valley tailings was not quantitatively evaluated. However, initial studies of the tailings revealed that the prospects of economically reprocessing the tailings were poor due to the low residual uranium, vanadium, and molybdenum contents of the tailings (FBDU, 1981b).

4.8 SITE ACQUISITION REQUIREMENTS

The Mexican Hat site is located within the Navajo Reservation. The DOE will enter into a land withdrawal agreement with the Navajo Nation for the area that will contain the stabilized tailings. Pursuant to that agreement, the DOE or another designated Federal agency will monitor and maintain the land containing the stabilized tailings.

The Monument Valley site is also located within the Navajo Nation. The entire site will be returned to the Navajo Nation after remedial action for any use consistent with land use controls.
5.0 WATER RESOURCES PROTECTION STRATEGY

The following is a summary of the water resources protection strategy for the Mexican Hat disposal site. A hydrogeologic characterization of the Mexican Hat site is presented in Appendix D, Section D.7; a more detailed analysis of this strategy is presented in Appendix E, Water Resources Protection Strategy.

The performance of the disposal cell is expected to comply with the site-specific groundwater protection standards as determined from an assessment of the hydrogeologic characteristics of the site, design analysis of the disposal unit, and performance assessment of the disposal site (NRC, 1988). The disposal cell will meet the proposed EPA MCLs or background water quality, whichever is higher, in the Honaker Trail Formation (the uppermost aquifer). Seepage of tailings fluids into the Honaker Trail Formation is precluded by the upward gradient between the Honaker Trail Formation and the Halgaito Shale Formation and a decrease in hydraulic conductivity with depth in the Halgaito Shale Formation in the area of the tailings piles. This upward hydraulic gradient is artesian in the vicinity of the tailings disposal cell. Because of the advantageous hydrogeologic setting, the remedial action is expected to comply with the proposed EPA groundwater protection standards.

The transient drainage of water added to suppress dust and compact relocated tailings, and tailings drainage that occurs prior to equilibration with the infiltration rate through the cover, should not cause the proposed EPA groundwater protection standards to be exceeded, as the seepage rate will be less than that which occurred from the tailings during processing activities. Because no contamination has been observed in the Honaker Trail Formation as the result of previous activities, concentrations of hazardous constituents in the Honaker Trail Formation should not be affected by the transient drainage of construction water and residual tailings fluids.

Qualitatively, several components of the cover design will provide additional conservatism for compliance with the proposed EPA groundwater standards. In the remedial action, the lower pile at Mexican Hat has been left in place and the upper pile was relocated and consolidated onto the lower pile. During the next phase of surface remedial action, the contaminated materials from Monument Valley will be relocated and consolidated onto the lower pile. The proposed cover design for the Mexican Hat disposal cell consists of a three-component cover system. In ascending order, the cover consists of a radon/infiltration barrier composed of highly compacted bentonite-amended soil; a bedding (filter) layer of sand; and an erosion protection layer of rock riprap. Recent studies on infiltration through radon barriers with similar cover components in areas with similar climates suggest that infiltration rates will be negligible, as infiltration is a function of the unsaturated hydraulic conductivity of the radon barrier (DOE, 1989b). The Mexican Hat disposal cell overlies the Halgaito Shale Formation, which unconformably overlies the Honaker Trail Formation in the site vicinity. The cell design favors the hydrogeologic isolation for moisture exiting the disposal cell. The design aligns the natural setting by incorporating a low cover flux and controlling the use of construction water. Unsaturated hydraulic conductivities are substantially lower than saturated hydraulic conductivities. Operational unsaturated conditions in the Mexican Hat radon/infiltration barrier result in an estimated seepage flux through the stabilized pile three to eight orders of magnitude less than the infiltration rate.
magnitude less than is occurring under presently unstabilized conditions. This represents a negligible long-term seepage flux through the disposal cell, implying that the proposed concentration limits (either background concentrations or MCLs, whichever is higher) would be met at the point of compliance (POC), even if the seepage could migrate into the Honaker Trail Formation.

The remedial action will meet the requirements of the standards because the proposed disposal cell design minimizes the need for active maintenance and minimizes or eliminates releases of hazardous constituents to groundwater. The need to minimize active maintenance is achieved by using natural, durable materials and shaping the pile to accommodate natural forces. The pile morphology has been designed to provide slope, settlement, and deformation integrity.

Pursuant to 10 CFR 40 and 40 CFR 192, the DOE is required to submit an LTSP that describes groundwater performance monitoring and demonstrates that the performance of the disposal cell is in accordance with the design requirements at the Mexican Hat Site. The LTSP will be supplied in a separate document. This plan will include a program for Gypsum Creek and North Arroyo seep monitoring. This seep monitoring program will provide a data base that will allow observation and prediction of seep water quality trends. This seep water quality data base will also provide information necessary to reach a decision as to the need for and extent of mitigative measures under Subpart B of UMTRCA as described below.

Closure performance monitoring of groundwater will not be needed at the Mexican Hat site. Water quality impacts in the Honaker Trail Formation have not been observed, even though processing activities began over 30 years ago. Because of the advantageous hydrogeologic setting, the water quality is not expected to be affected in the future.

If the proposed EPA groundwater standards are found or projected to be exceeded, a corrective action plan will be proposed to bring the disposal site into compliance. Proposing a specific detailed action plan to clean up or control the movement of groundwater at this time is not possible. However, should a failure of the disposal cell occur, or should the site be found not to be in compliance following tailings stabilization, within 18 months corrective action plans shall be formulated and implemented.

Based on the present level of site characterization, no groundwater cleanup is anticipated at the Mexican Hat processing site. The uppermost aquifer, the Honaker Trail Formation, has not been and is not expected to be influenced by tailings seepage. The zone of saturation in the Halgaito Shale Member that resulted from uranium processing will eventually diminish as recharge through the tailings is limited by the consolidation of the tailings into a disposal cell with a cover that restricts infiltration. Although this Halgaito Shale Formation saturation contributes to Gypsum Creek seep discharges, a human health and ecological risk assessment (JEG, 1990) found that negligible risk was associated with the seeps given their remote location from human activity and livestock. The seeps in the North Arroyo and in Gypsum Creek will continue to be monitored until the need for mitigative measures is assessed under the separate NEPA process.

Groundwater in the vicinity of the Mexican Hat tailings site has never been used as a water resource due to the naturally poor quality and limited yield. Based on the historic record of groundwater use and the present and future
availability of alternative water supplies, groundwater at the site is not projected to constitute a viable water resource in the area. After remedial actions are completed at the Mexican Hat disposal site, groundwater within the Halgaito Shale Formation will disperse for an unknown, but finite, time. Eventually, recharge to the Halgaito Shale Formation will be governed by infiltration of precipitation, which will result in a return to unsaturated conditions, as was likely the case prior to uranium milling operations. Existing saturation within the Halgaito Shale Formation will diminish with time.

The need for and extent of groundwater cleanup at the Monument Valley processing site will be determined based on the extent of the existing contamination, the potential for current or future use of the aquifer for drinking water supplies, and the technical practicability of restoring the aquifer from an engineering perspective. The relocation of the Monument Valley processing site tailings to the Mexican Hat disposal site will remove the source term for the groundwater contamination at Monument Valley. This will not affect the ability to perform groundwater cleanup at the Monument Valley site. Studies are currently under way to develop plans, guidance materials, and procedures for groundwater cleanup activities. The decision as to the need for and extent of groundwater cleanup, required to be addressed under 40 CFR 192 Subparts B and C, will be made as part of a separate process under the NEPA. These investigations will be carried out during the Subpart B groundwater restoration phase.
6.0 ENVIRONMENTAL, HEALTH, AND SAFETY

6.1 POLICY

The UMTRA Project health and safety policy is that the DOE and its contractors will take all reasonable precautions in the performance of the remedial action work to protect the environment, ensure the health and safety of employees and the public, and provide protection of the government. The DOE and its contractors will comply with all applicable Federal and state/tribal health and safety regulations and requirements including, but not limited to, those established pursuant to the Occupational Safety and Health Act (OSHA).

The site Remedial Action Contractor (RAC) will have the principal responsibility for implementing a health and safety program. The program should include an on-site professional health and safety staff responsible for implementing, monitoring, sampling, training, and reporting procedures. The surrounding community and the on-site workers must be protected from accidents and radiation exposure. The RAC health and safety program will meet all of the requirements of the UMTRA Project Environmental, Health, and Safety Plan (DOE, 1989c) or its revisions, as well as DOE Orders 5400.5 and 5480.11.

6.2 SITE CONDITIONS AFFECTING HEALTH AND SAFETY PLANNING

The remedial actions at the Mexican Hat and Monument Valley sites will require special attention to potential hazards because of the wide range of activities conducted at the sites during their operation, the various toxic and hazardous materials that may remain at the sites, and the physical hazards that exist at the sites. This section describes those specific conditions that are known or suspected to exist at the sites, and that will require special attention in the health and safety program to be implemented by the RAC.

A sulfuric acid plant was constructed and operated at the Mexican Hat site. As a result, soil in the area of the plant is highly acidic. Caution should be exercised to prevent manual handling of the material. Steep slopes and cliffs are present in the vicinity of the sites. Poisonous snakes have been observed in the local area of the sites.

While no known Th-230 separation was performed at the Mexican Hat site, measurements of Th-230 in air particulates collected in the mill yard, as well as adjacent to the tailings pile, have resulted in average values about 15 percent of the maximum permissible concentration (MPC). Thorium concentrations as high as 56 percent of the MPC were measured at the Monument Valley site. These samples were collected during a period of no construction activity. Th-230 levels in air particulates during construction may approach and even exceed the administrative limits despite ongoing efforts to minimize dust generation. This would necessitate the use of respirators.
The nearest hospital with 24-hour emergency service is the Monument Valley Adventist Hospital. The nearest Highway Patrol office is in Monticello, Utah. Phone numbers for contacting emergency response organizations are provided below:

<table>
<thead>
<tr>
<th>Service</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance</td>
<td>(801) 587-2232</td>
</tr>
<tr>
<td>Monument Valley Adventist Hospital</td>
<td>(801) 727-3242</td>
</tr>
<tr>
<td>Fire Department</td>
<td>(801) 587-2237</td>
</tr>
<tr>
<td>Highway Patrol</td>
<td>(801) 587-2116</td>
</tr>
<tr>
<td>Navajo Police, Kayenta</td>
<td>(602) 697-3578</td>
</tr>
</tbody>
</table>
7.0 RESPONSIBILITIES OF PROJECT PARTICIPANTS

7.1 INTRODUCTION

The following defines the various responsibilities of the DOE UMTRA Project Office, the NRC, the Navajo Nation, the Bureau of Indian Affairs (BIA), and the Bureau of Land Management (BLM) during design, remedial action, and through the initiation of custodial surveillance and maintenance. The DOE will be assisted by its Technical Assistance Contractor (TAC) and its RAC, Morrison-Knudsen, Inc. However, all assigned responsibilities will remain the ultimate responsibility of the DOE. In general, the TAC will assist the DOE in the preparation of conceptual designs and a remedial action plan, and will provide quality assurance, audits, and recommendations for final certification. The RAC will prepare detailed design and manage field construction activities. The Navajo Nation's responsibilities will be administered and coordinated by the Navajo Division of Resources.

Major areas of responsibility for future actions by the DOE, the Navajo Nation, the NRC, the BIA, and the BLM are summarized as follows:

**DOE (including TAC and RAC):**

Manage and coordinate project.
Obtain permits and approvals.
Prepare detailed design and specifications.
Prepare quality assurance plan.
Prepare and implement public participation and information plan.
Provide funds.
Conduct remedial action.
Audit remedial action.
Prepare and submit license application.
Prepare LTSP.
Certify remedial action.
Obtain license.
Conduct surveillance and maintenance.

**Navajo Nation:**

Review and concur in the RAP.
Assist the DOE in acquiring or extinguishing the interests of landowners or others with property interests at the designated processing and disposal sites.
Assist in obtaining local Chapter and Tribal Council approvals.
Issue Navajo Tribal permits or approvals.
Assist in public participation and information.
Assist in the land acquisition process.

**NRC:**

Review and concur in the RAP.
Review and concur in the LTSP.
Review and concur in the final certification report. Issue a license for long-term surveillance and maintenance of the disposal site.

BIA:
Review and concur in the RAP. Issue sand and gravel permits for excavation of borrow materials. Assist the DOE in acquiring or extinguishing the interests of those with property interests at the designated processing site. Concur in the land acquisition process.

BLM:
Issue free use permit for the extraction of gravel and rock.

7.2 DETAILED RESPONSIBILITIES

Detailed responsibilities of the project participants in the areas of permitting, licensing, land acquisition, detailed design, construction, health and safety, public information, radiological support, quality assurance, and custodial surveillance and maintenance are defined in the following sections.

7.2.1 Regulatory compliance

Requirements for regulatory compliance, previously identified by Federal and state agencies (Agencies), will be incorporated into the final design specifications, as needed, by the DOE. Revisions to the design and specifications resulting from internal DOE reviews will be incorporated prior to the Agencies' review for permits.

The RAC will submit permit applications and supporting details to the Agencies for permit issuance.

During the remedial action, the DOE will audit construction activities for compliance with provisions of the permits and approvals (permitting Agencies may independently audit relevant activities consistent with normal practice). Summary audit reports will be prepared by the DOE and submitted to the appropriate Agencies as required. Depending upon Agency comments, revisions to construction compliance activities will be made.

Upon completion of the permitted action, the DOE will conduct a final review and will prepare a close-out report for submittal to the Agencies as required. Permits will then be terminated.
7.2.2 Licensing

As part of the licensing task and prior to completion of the remedial action, the DOE will prepare a draft license application including the site LTSP. The draft application will be submitted to the NRC for review and comment. Revisions resulting from this review will be incorporated into the final application, which will be submitted to the NRC by the DOE following the completion of remedial action and documentation in a certification report.

Any final revisions required will be added and the licenses will be issued by the NRC to the DOE (or responsible designated Federal agency).

7.2.3 Land acquisition

The Navajo Nation and the BIA will assist the DOE in acquiring or extinguishing the interests of assignees, permittees, lessees, sublessees, or other individuals with property interests in the processing and disposal site. Upon completion of the remedial action, the DOE will execute the long-term custody agreement for the long-term surveillance and maintenance of the site by the Federal government.

7.2.4 Detailed design

The RAC prepared preliminary engineering drawings for review by the DOE. Based upon this review, the RAC will prepare final design drawings, specifications, and bid packages. Once final and approved by the DOE, the bid packages will be issued to prospective bidders pursuant to Federal regulations, and a construction subcontractor(s) will be selected.

Final design and specifications are provided in Appendix B, Specifications, Design Drawings, Calculations, and Information for Bidders.

7.2.5 Construction

The DOE will prepare guideline documents to comply with health and safety, security, quality assurance, public information, and other regulatory requirements.

The RAC will acquire the necessary permits and approvals from the appropriate Agencies.

Site mobilization and initiation of construction activities will occur in accordance with the DOE-approved construction schedule.
Construction activities will be audited by the DOE. These audits will be provided to the NRC and the Navajo Nation and to other regulatory Agencies upon request to the DOE. The Navajo Nation, the NRC, and other regulatory Agencies may also perform independent audits of the remedial action. Revisions to the remedial action resulting from site audits will be incorporated into the as-built design and the RAP by the DOE as necessary.

Upon completion of the remedial action, the sites will be certified by the DOE. The NRC will review and concur in the final site certification report.

7.2.6 Health and safety

Based upon the guidance of the UMTRA Project—Environmental, Health, and Safety Plan (DOE; 1989c), site-specific implementation methods will be developed by the RAC. As part of the implementation methods, the RAC will institute radiation control and environmental monitoring and will develop response procedures for severe weather and medical emergencies.

Construction contractors will comply with approved procedures, file reports with the DOE that record the results of monitoring, and report accidents and illnesses. Records will be maintained by the DOE following remedial action construction.

Employee and public complaints will be investigated by the DOE.

7.2.7 Public information

The DOE will establish local site managers who will provide information to the public and local media.

Prior to and during construction, the DOE, with assistance from Navajo Nation officials and local citizens, will conduct public information meetings to inform the interested public of key aspects and current progress of the remedial action.

Concurrent with the public meetings, the DOE will provide status and progress reports for the Navajo Nation and other agencies (e.g., NRC, EPA, BIA).

7.2.8 Radiological support

The DOE will prepare and implement a Radiological Support Plan (Appendix C) and will take measures to independently ensure the quality of the analyses and compliance with the procedures.

After remedial action, the DOE will prepare a completion report, conduct a final verification survey, and provide a recommendation for
site certification. The NRC will concur in the final site certification report.

7.2.9 **Quality assurance (QA)**

Quality will be controlled in accordance with the DOE/UMTRA Quality Assurance Plan (DOE, 1990). QA audits and the in-process surveillance shall be conducted by DOE and the TAC to verify and ensure that the remedial action activities are performed in accordance with approved Project requirements.

7.2.10 **Surveillance and maintenance**

The DOE will prepare and submit to the NRC the LTSP as part of the site license application. The NRC will review and concur with the plan, and the DOE (or designated Federal agency) will ensure that the plan is implemented.
8.0 LONG-TERM CARE PROGRAM

8.1 INTRODUCTION

To control the stabilized RRM, Section 104(f)(2) of the UMTRCA requires that the disposal sites be cared for under a general license issued by the NRC. The NRC's regulations, 10 CFR 40, define the conditions that must be met before the general license becomes effective for the disposal site at Mexican Hat, Utah.

The general license is for the disposal sites only. Its objective is to ensure that the disposal cell remains undisturbed and that the stabilized RRM will not present a hazard to the public or the environment. The general license will become effective for the Mexican Hat disposal site after the following take place:

- The NRC concurs in the DOE's certification that the remedial action has been completed in accordance with 40 CFR 192 and all applicable standards for the Navajo Nation.
- Title to or custody of the RRM and the disposal site has been transferred to the DOE.
- The NRC has formally accepted the site-specific LTSP.

At this time, surveillance and monitoring (S&M) under the Title I long-term care program will begin and programmatic responsibility for carrying out this program will be transferred to the DOE Grand Junction Projects Office (GJPO).

It is estimated that once the surface remedial action activities are completed, it will take a minimum of 28 months for the licensing process to be completed.

8.2 THE LONG-TERM SURVEILLANCE PLAN

The LTSP contains the licensing conditions for the Mexican Hat disposal site. As defined in 10 CFR 40.27b, the LTSP will contain the following information:

- A legal description of the disposal site to be licensed, including documentation on whether land and interests are owned by the United States or an Indian tribe.
- A detailed summary description of the final site conditions, specific maps and drawings of permanent site surveillance features, and a characterization of existing groundwater quality and any necessary groundwater protection activities or strategies.
A detailed description of the long-term surveillance program, including the proposed inspection frequency, reporting to the NRC, and the extent of groundwater monitoring, if required.

The criteria for follow-up inspections in response to observations from routine inspections or extreme natural events.

The criteria for instituting maintenance or emergency measures (e.g., corrective action).

The Guidance for Implementing the UMTRA Project Long-term Surveillance Program (DOE, 1992) provides guidance for carrying out the long-term care program in accordance with the licensing conditions and for preparing the LTSP.

At the time the disposal site is completed, a draft LTSP will be prepared for review and comment by the NRC and the Navajo Nation. The final LTSP will be submitted to the NRC for acceptance after their concerns and those of the Navajo Nation have been addressed, and after the NRC has concurred in the DOE's certification of completion of remedial action and custody of the RRM and the disposal site has been transferred to the DOE.

For the disposal site at Mexican Hat where the RRM is to be stabilized in place (SIP), a two-step process will be applied to 1) the NRC's concurrence in the DOE's certification that surface remedial action is completed, and 2) the licensing process. The two-step process will avoid delaying the licensing of the disposal site so that surveillance and monitoring under the long-term care program can begin. When any groundwater restoration activities that may be required have been addressed, the NRC will then concur in the second phase of the DOE's certification and the second, and final, phase of the license will be in effect for this SIP site.

When the NRC concurs that all groundwater restoration activities have been addressed at the Mexican Hat disposal site, the need to modify the LTSP will be assessed and reported to the NRC.

8.3 THE LONG-TERM CARE PROGRAM

8.3.1 Baseline conditions

The LTSP will describe the final site as-built conditions. It will contain a summary of the disposal cell design and a description of baseline conditions, including groundwater characterization. In addition to the site as-built drawings, aerial photographs will be taken to visually record baseline conditions. These photographs also will be used to supplement the site inspections to identify changes in site conditions (e.g., patterns of developing erosion that may affect the function of the disposal cell design). If potential problems are identified over time, additional aerial photographs will be taken to aid in the determination of the long-term effect of the problem.
8.3.2 **Groundwater monitoring**

The need for groundwater monitoring is identified and described in the RAP. The LTSP will provide a summary of the groundwater protection strategy identified in the RAP. The LTSP also will include the following:

- A summary of the hydrogeologic conditions, including background and baseline groundwater conditions.
- The identification of hazardous constituents to be monitored, their established concentration limits, and excursion criteria.
- The seep monitoring network, including the number and location of the seeps. Site surveyed coordinates and ground elevations will be kept in the permanent site file to be used by GJPO in long-term surveillance.
- Seep water quality and water flow data summaries. Reference to the complete reports on groundwater quality will be provided.
- The frequency and extent of the groundwater monitoring program.

8.3.3 **Site inspections**

The most effective way of ensuring that the disposal cell is functioning as designed is by conducting on-site inspections. The primary objective of the site inspection is to record any changes or modifications to the disposal cell and disposal site over time and identify potential problems at an early stage prior to the need for extensive maintenance, repairs, or corrective action.

**Scheduled inspections**

Site inspections will be conducted annually for the first five years after the site is licensed. At the end of this five-year period, the DOE will review all inspection reports, as well as any maintenance or corrective action reports. If a determination is made that less frequent inspections are required, the DOE will modify the LTSP and submit it to the NRC for acceptance. The Navajo Nation also will receive a copy for review.

**Follow-up inspections**

Follow-up inspections are a second level of inspection to investigate and further quantify specific site problems detected during a scheduled inspection. A follow-up inspection could be
required to evaluate the need for custodial maintenance, repair, or corrective action. These inspections will be conducted by technical specialists in the discipline appropriate to a reported problem. Based on the recommendations from this inspection, a program of evaluative monitoring may be recommended, or a corrective action program may be initiated.

At the conclusion of the follow-up inspection, an inspection/preliminary inspection report will be submitted to the NRC within 60 days of the initial report of the problem. The DOE also will provide copies of these reports to the Navajo Nation within the 60-day time frame.

Contingency inspections

Contingency inspections are unscheduled inspections ordered by the DOE when it receives outside information indicating that the disposal site integrity has been threatened. This inspection could be triggered by unusual events such as a report of severe vandalism, continuing intrusion by livestock, or a report of an extreme natural event such as flooding or, possibly, an earthquake.

The procedures for conducting a contingency inspection, as well as the reporting requirements, are the same as those for a follow-up inspection.

To ensure that the DOE is notified promptly of unusual or extreme events, the DOE will implement the contingency plans and reporting procedures with appropriate state, local, and Federal agencies (e.g., the National Weather Service and the Earthquake Information Center) when the LTSP is under preparation.

8.3.4 Custodial maintenance or repair

The need for custodial activities can be determined only during the site inspection. It is anticipated that custodial maintenance or repair would be limited to fence or sign repair or weed control. The final LTSP will identify any planned custodial activities that may be required, the timing and frequency with which they will be performed, and the manner in which the work will be authorized.

8.3.5 Corrective action

The need for corrective action will be defined by the nature and magnitude of the problem and its effect on the disposal cell's ability to comply with the EPA standards. If the need for corrective action is indicated, the DOE will initiate a program to identify the factors that caused the problem and to determine the best course of action for correcting the problem and ensuring that its recurrence is precluded.
Once a potential problem is identified, the DOE will notify the NRC and will submit an inspection/preliminary assessment report to the NRC for review within 60 days of the report of the problem. After NRC review, the DOE will develop a corrective action program for NRC approval. Copies of these reports will be provided to the Navajo Nation for review. Once the NRC has approved the corrective action, the plan will be implemented by the DOE.

If an excursion is identified during the groundwater monitoring program, 40 CFR 192.02(c) requires that corrective action be implemented within 18 months of verification of the excursion.

### 8.3.6 Reporting and record keeping

The DOE will prepare a report to the NRC that provides the results of scheduled inspections, groundwater monitoring results, and the results of any unscheduled inspections, repairs, or corrective actions that may have been required at the disposal site. This report will be prepared annually, in accordance with the requirements of 10 CFR 40. A copy of this report also will be provided to the Navajo Nation.

The DOE will maintain complete records and supporting documentation in permanent site files. The reports, records, and supporting documentation will: 1) demonstrate that the license provisions continue to be met; 2) provide the DOE and NRC information necessary to forecast future surveillance and monitoring; and 3) provide information to the public to demonstrate that site integrity is being maintained.
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