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

REMEDIAL ACTION PLAN FOR STABILIZATION
OF THE
INACTIVE URANIUM MILL TAILINGS SITE
AT
MONUMENT VALLEY, ARIZONA

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1.0 INTRODUCTION

1.1 PURPOSE

This Remedial Action Plan (RAP) has been developed to serve a twofold purpose. It presents the series of activities which are proposed by the U.S. Department of Energy (DOE) to accomplish long-term stabilization and control of radioactive materials at the inactive uranium processing site located near Monument Valley, Arizona. It also serves to document the concurrence of both the Navajo Nation and the U.S. Nuclear Regulatory Commission (NRC) in the remedial action. This agreement, upon execution by DOE and the Navajo Nation and concurrence by 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 sites to be designated for remedial action. On November 9, 1979, Monument Valley was designated as one of the 24 sites.

UMTRCA charged the Environmental Protection Agency (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 non-radiological 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 UMTRCA, the DOE and the Navajo Nation entered into a cooperative agreement effective October 7, 1983, for remedial action at the Monument Valley site. The DOE will fund 100 percent of allowable costs.

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. A detailed listing of the responsibilities of the project participants is included in Section 7.0 of this report.

1.3 SCOPE AND CONTENT

This document has been structured to provide a comprehensive understanding of the remedial action proposed for the Monument Valley site. It
includes specific design requirements for the detailed design and construction of the remedial action. An extensive amount of data and supporting information have been generated for this remedial action which cannot all be incorporated into this single document. 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 Conceptual Design (SCD) for the proposed action. Section 5.0 summarizes the plan for ensuring health and safety protection for the surrounding community and the on-site workers. Section 6.0 presents a detailed listing of the responsibilities of the project participants. Section 7.0 describes the features of the long-term surveillance and maintenance plan. Section 8.0 presents the quality assurance aspects of the project. Section 9.0 documents the ongoing activities to keep the public informed and participating in the project.

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

Appendix A, Regulatory Compliance, describes in detail the permits necessary for the remedial action activities.

Appendix B, Engineering Design, presents a summary of rationale and calculations that support the conceptual design and the concept drawings.

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 all pertinent data necessary for the design of the proposed remedial action. Appendix D contains all of the geotechnical, hydrological, radiological, meteorological, and physical data necessary to describe the existing conditions at the site.

1.4 COLLATERAL DOCUMENTS

The Environmental Assessment (EA) (DOE, 1985b) describes the existing conditions at the site and the results of the remedial action. The EA describes the proposed remedial action and alternatives and the environmental impacts of the proposed actions and includes details that are not reported in the RAP.

An additional supporting document is the Technical Approach Document (DOE, 1985c). 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 ground-water resources.

Copies of these documents, as well as supporting data and calculations, 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 Sites (DOE, 1984b). That document was used as a guide in the development of the Remedial Action Plan. This EPA Standards section has been extracted from the above-referenced publication.

2.1 GENERAL

Pursuant to the requirements of the UMTRCA, EPA has promulgated health and environmental standards to govern cleanup, stabilization, and control of residual radiological materials 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 ground-water quality.

In developing the standards, 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 secondary 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." (Ref. preamble to Standards for Remedial Actions at Inactive Uranium Processing Sites, 40 CFR Part 192.) These conclusions were based on a determination that the most significant public health risks associated with inactive tailings were posed by exposure to people living and working in structures contaminated by relocated tailings. EPA further concluded that the potential for contamination of ground water 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 which would be effective only for a short period of time and which 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.
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 UL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 UL, 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

-6-
Active control covers could be expected to need frequent replacement or other major repairs requiring the appropriation and expenditure of public funds. In setting the standards, EPA called for designs which rely primarily on passive controls.

The standard is framed as a longevity requirement which recognizes the difficulty in predicting very long-term performance with a very high degree of confidence. In establishing the longevity requirement, 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 such as custodial maintenance, monitoring, and contingency response measures. In its preamble to the standards, EPA calls for such controls to be provided as an essential backup to the primary passive controls.

2.3 RADON EMISSIONS CONTROL

EPA identified a reduction of radon emission from tailings piles as the second objective in its standards for the control of tailings. In developing the standards, EPA considered several alternative approaches and selected an emission limitation as the primary form of the standard. In addition, a concentration limit was established by 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, EPA sought to reduce both the maximum risk to individuals living very near to the sites and the risk to the population as a whole. With regard to individuals very near to disposal sites, EPA estimates that exposure to radon emissions will be reduced by more than 96 percent. 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. 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, 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-QUALITY PROTECTION

EPA reviewed available water-quality data at inactive tailings sites and determined that there was little evidence of recent movement of
contaminants into ground water. They also determined that any degradation of ground-water quality should be evaluated in the context of potential beneficial uses of the ground water as determined by background water quality and the available quantity of ground water.

Rather than establish specific numerical limitations for contaminant discharges or ground-water quality, EPA determined that the most appropriate course of action would be to require site-specific analyses of potential future contaminant discharge and a case-by-case evaluation of the significance of such a discharge. The implementation guidelines for the EPA standards call for adequate hydrological and geochemical surveys at each site as a basis for determining whether specific water-protection measures should be applied. On September 3, 1985, the United States Circuit Court of Appeals set aside EPA's water protection standards, 40 CFR Part 192.20(a)(2)-(3), and EPA has not yet reissued these standards. The Environmental Assessment identifies how DOE will approach this issue until water protection standards are reissued.

Specific site assessments must include monitoring programs sufficient to establish background ground-water quality through one or more upgradient wells, and to identify the present movement and extent of contaminant plumes associated with the tailings piles. The site assessments further call for judgements of the need for restoration or prevention, or both, to be guided by EPA's hazardous waste management system and relevant state and Federal water-quality criteria. Decisions on specific actions to protect or restore water quality are to be guided by such factors as the technical feasibility of improving the aquifer, the cost of applicable restorative or protective programs, the present and future value of the aquifer as a water source, the availability of alternate water supplies, and the degree to which human exposure is likely to occur.

The UMTRCA requires that the standards promulgated by EPA "...to the maximum extent practicable, be consistent with the requirements of the Solid Waste Disposal Act, as amended." In setting the standards, EPA determined that the statutory requirement for NRC to concur with the selection and performance of remedial actions and to issue licenses encompassing "monitoring, maintenance, or emergency measures necessary to protect public health and safety" was consistent with the EPA regulations implementing the Solid Waste Disposal Act (47 FR 32274, July 26, 1982). Accordingly, EPA established the implementation procedures requiring case-by-case evaluations of potential contamination at sites. Decisions regarding monitoring or remedial actions will be guided by relevant considerations in the hazardous waste management systems.

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. EPA therefore stated
that the objective of the cleanup of tailings from around existing structures was to achieve an indoor radon daughter concentration (RDC) of less than 0.02 WL (working level). For open lands, the purpose of removing the contamination is to remove the potential for excessive indoor radon daughter concentrations that might arise from new construction on contaminated land. The 5 pCi/g and 15 pCi/g Ra-226 concentration limits for 15-cm surface and subsurface layers were considered adequate to limit indoor RDCs to below 0.02 WL. A secondary concern was to limit exposure to people from gamma radiation.

The standard requires that residual radioactive materials 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 presents a summary of the current conditions of the Monument Valley site with emphasis given to radiation, geology, and ground water due to their importance in the remedial action design. The detailed characterization of the site is found in Appendix D, Site Characterization.

3.1 SITE DESCRIPTION

The Monument Valley site is approximately five miles south of the Utah-Arizona border in Cane Valley just east of Monument Valley, Arizona, within the Navajo Reservation (Figure 3.1). The area is arid desert terrain. Major topographic features of the area include Comb Ridge to the east and Yazzie Mesa to the west. Vegetation is sparse with blackbrush the predominant plant species. Livestock grazing and residences are the major land uses.

The designated site (Figure 3.2), covering 100 acres, consists of two piles, concrete foundations, truck ramps, and some rubble. Site buildings have been dismantled and removed, or buried in the new tailings pile.

The mill was constructed and operated by Vanadium Corporation of America and its successor, Foote Mineral Company, from 1955 to 1968. The source of the ore was Monument No. 2 Mine, located 0.5 mile west of the tailings. More than one million tons of low-grade ore were processed at this site.

3.2 RADIATION

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

Radiological data have been collected from the vicinity of the site in numerous investigations since 1967 (see Appendix D, Site Characterization). 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

Background radioactivity data provide a reference point 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.
FIGURE 3.1
MONUMENT VALLEY SITE
TO MEXICAN HAT, UTAH 18 MILES

NAVAJO TRIBE

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 2,158,200 X E 587,000 AND RUNNING THENCE S 2° E, 1300 FT, THENCE S 87° W, 741,84 FT, THENCE N 50° E, 869.63 FT, THENCE N 40° E, 1000 FT, THENCE S 10° E, 1000 FT, THENCE N 87° E, 1150 FT TO THE POINT OF BEGINNING.

CONTAINS 101 ACRES (MORE OR LESS)

NO SCALE

FIGURE 3.2
MONUMENT VALLEY SITE DESIGNATION
The complex mineralization in the Monument Valley area makes assignment of background levels difficult. The average background Ra-226 level in the alluvium near the new pile area (not influenced by tailings) is 1.0 pCi/g. Uranium deposits exist within several thousand feet of the tailings in the Shinarump Formation which comprises the western half of the site. In addition, several local potassium-rich radioactive siltstone deposits were used for construction around the site.

The average background gamma radiation exposure rate from both terrestrial and cosmic sources measured three feet above the ground is 11 microR/hr. Again, a relatively wide variation in background levels is due to the complex pattern of uranium and potassium mineralization in the area.

The average outdoor background radon concentration is unknown at this time. Previous short-term measurements have ranged from 0.1 to 0.7 pCi/l. To determine annual average background Ra-226 levels, a program is currently being implemented. Quarterly average measurements made at approximately 20 locations around the site for an entire year using integrating film-type radon detectors are currently in progress.

3.2.2 Existing conditions

The radioactive materials at the Monument Valley site cause the ambient radiation to be above natural background. Measurements of on-site gamma exposure rates and airborne particulates are summarized below (see Appendix D, Site Characterization). These are important in estimating the radiological hazard presented by the site.

The 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 Ci/yr of radon are released from all contaminated materials on the site.

The vast majority 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 whereby 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 Th-230 levels up to 56 percent of the levels allowed for continuous exposure by the public.

3.2.3 Contaminant distribution

The contaminated areas of the Monument Valley site and its vicinity are shown in Figure 3.3. The origin and extent of the contamination are summarized below.

-14-
FIGURE 3.3
LIMITS OF CONTAMINATION, MONUMENT VALLEY SITE
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 (702,000 cy) is in and beneath the new pile and pond area. The new pile is a cone about 1000 feet in diameter and about 60 feet high. It is easily discerned in the isometric view of the existing topography of the site shown in Figure 3.4. An additional 197,000 cy are in and beneath the heap leach pads. The material beneath the tailings in the new pile and leached ore in the heap leach pads is contaminated but only about a foot deeper than the physical interface.

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. This area is referred to as Area E in subsequent discussions.

In October, 1964, equipment was installed for batch leaching of the sand fraction. This area was built up and leveled using pit run rock (Area C) and is located between the heap leach pads and the new pile. As a result, both Areas E and C are mildly contaminated (14,000 and 28,000 cy, respectively). The batch leach operation processed the coarse sand fraction from the area of the heap leach pads and the resulting tailings were used to form what now is the new pile. A small remnant of the original old pile of coarse fraction material comprises Area D (Figure 3.4). 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 (about minus one inch). This material was heap leached in place and has remained undisturbed to the present.

A small area to the northeast of the heap leach pads and immediately to the north of the batch leach area is also contaminated with what appear to be windblown tailings; however, the windblown area to the north of the new pile is only several hundred feet in extent. This indicates that the material to the northeast of the heap leach pads is remnant tailings left over from the batch leach operation, and not windblown.

Other areas near the site also have small amounts of contamination. About 20 sites to the north of the former ore storage and mill yard area contain piles (10-foot radius and one foot deep) of rubble which are slightly contaminated. These appear to be associated with housing (temporary structures) for the mine and mill workers. In addition, roads built for the mine and mill operations were constructed 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 which
FIGURE 3.4
ISOMETRIC VIEW OF THE EXISTING TOPOGRAPHY AT THE MONUMENT VALLEY SITE
appears to have been taken from the 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 around the site cross the many arroyos.

Table 3.1 summarizes the volumes and Ra-226 concentrations of all major areas on the site. A more detailed presentation of the distribution of contamination can be found in Appendix D, Site Characterization.

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

<table>
<thead>
<tr>
<th>Description</th>
<th>Contaminated volume (cy)</th>
<th>Surface area (ac)</th>
<th>Average depth (ft)</th>
<th>Ra-226 average concentration (pCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New pile and pond area</td>
<td>702,160</td>
<td>24.6</td>
<td>17.7</td>
<td>65</td>
</tr>
<tr>
<td>Heap leach pads</td>
<td>197,070</td>
<td>10.6</td>
<td>11.5</td>
<td>54</td>
</tr>
<tr>
<td>Ore storage and mill yard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Area E</td>
<td>13,690</td>
<td>23.9</td>
<td>0.4</td>
<td>64</td>
</tr>
<tr>
<td>Batch leach yard - Area C</td>
<td>27,930</td>
<td>7.5</td>
<td>2.3</td>
<td>45</td>
</tr>
<tr>
<td>Old pile remnant - Area D</td>
<td>3,200</td>
<td>1.0</td>
<td>2.0</td>
<td>45</td>
</tr>
<tr>
<td>Rubble piles</td>
<td>300</td>
<td>0.2</td>
<td>1.0</td>
<td>25</td>
</tr>
<tr>
<td>Roads</td>
<td>2,400</td>
<td>1.5</td>
<td>1.0</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>946,750</td>
<td>69.3</td>
<td>8.5</td>
<td>62</td>
</tr>
</tbody>
</table>

3.3 GEOLOGY, GEOMORPHOLOGY, AND SEISMICITY

3.3.1 Introduction

Detailed investigations of geologic, geomorphic, and seismic conditions at the Monument Valley UMTRA Project site were conducted by the DOE. The purpose of these studies is basic site characterization and identification of potential geologic hazards which could affect long-term site stability. Subsequent engineering studies, such as analyses of hydrologic and liquefaction hazards, utilized the data developed in these studies. The geomorphic analysis was employed in the design of effective erosion protection. Studies of the regional and local seismotectonic setting, which included a detailed search for possible capable faults within a 65-km radius of the site, provided the basis for estimation of seismic design parameters. The findings of these investigations are discussed in detail in Appendix D, Site Characterization, Section D.4, and are briefly summarized here.
The scope of work performed included the following:

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

### 3.3.2 Geologic setting

The Monument Valley UMTRA Project site is located in the northern part of the Navajo section of the Colorado Plateau physiographic province (Hunt, 1967) (Figure 3.5). 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 fantastic array of mesas, buttes, spires, and pinnacles (Stokes, 1973). Preservation of many of these monuments seems to have resulted from protection of underlying rocks from erosion by a resistant caprock, formed by the Triassic Shinarump Conglomerate Member of the Chinle Formation. The Shinarump is the major source of uranium-vanadium deposits in the site region, and also is the major unit underlying the existing tailings piles.

Bedrock in the site region consists predominantly of marine to continental sediments ranging in age from Late Paleozoic to Jurassic (Witkind, 1956; Witkind and Thaden, 1963; O'Sullivan and Beikman, 1963; Haynes et al., 1972; Hackman and Wyant, 1973; Haynes and Hackman, 1978) (Figure 3.6). 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, chiefly eolian and alluvial in origin, of Quaternary age.

### 3.3.3 Site geology

In 1951 and 1952, the U.S. Geological Survey carried out a program of geologic mapping and uranium investigations in Apache
FIGURE 3.5

PHYSIOGRAPHIC MAP OF THE COLORADO PLATEAU
SHOWING LOCATION OF MONUMENT VALLEY SITE

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.
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. Monument Valley Nat. Mon.
23. Tusigoot Nat. Mon.

Escarpments 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
### Table: Columnar Section of Consolidated Sedimentary Strata Exposed in the Monument Valley Site Area

<table>
<thead>
<tr>
<th>Formation</th>
<th>Age</th>
<th>Rock Type</th>
<th>Thickness (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glen Canyon</td>
<td>Jurassic</td>
<td>Navajo sandstone</td>
<td>575-665</td>
<td>Pink and buff massive eolian crossbedded sandstone with interbedded thin lenses of shales, limestones, forms cliffs, locally weathers to rounded forms; constituents include quartz, feldspar, zircon, garnet, and magnetite.</td>
</tr>
<tr>
<td>Kayenta formation</td>
<td>Jurassic</td>
<td>Wingate sandstone</td>
<td>210-360</td>
<td>Light blue-gray alternating claystone and ledge-forming cherty limestone.</td>
</tr>
<tr>
<td>Church Rock</td>
<td>Jurassic</td>
<td>Glen Canyon sandstone</td>
<td>150-250</td>
<td>Reddish-brown massive eolian crossbedded siltstone and sandstone of uniform texture; forms cliffs; constituents include quartz, feldspar, zircon, and garnet.</td>
</tr>
<tr>
<td>Owl Rock</td>
<td>Jurassic</td>
<td>Kayenta formation</td>
<td>120-165</td>
<td>Reddish-orange crudely bedded blocky crossbedded siltstone and sandstone that is in part subaqueous and in part eolian; weathers to rubble-covered slopes.</td>
</tr>
<tr>
<td>Petrified Forest</td>
<td>Upper Triassic</td>
<td>Chinle formation</td>
<td>510-620</td>
<td>Variegated massive uniform-textured well-indurated mudstone, claystone, and siltstone with local lenses of mud-pebble conglomerate, bentonic.</td>
</tr>
<tr>
<td>Monitor Butte</td>
<td>Upper Triassic</td>
<td>Chinle formation</td>
<td>80-200</td>
<td>Dark-gray fluvialid crossbedded lenticular sandstone and conglomerate, locally broken and folded into intraformational structures of all types; much silicified wood included; major constituents are quartz, quartzite, and chert; intertongues with Shinarump member.</td>
</tr>
<tr>
<td>Shinarump</td>
<td>Lower and Middle Triassic</td>
<td>Moenkopi formation</td>
<td>0-150</td>
<td>Light-gray fluvialid crossbedded conglomeratic quartz sandstone with intercalated conglomerate lenses, much silicified wood and clay pebbles included; major constituents are quartz, quartzite, and chert; forms caprock of mesas, has scour channels at base. Uranium bearing locally.</td>
</tr>
<tr>
<td>Hoskinman tongue</td>
<td>Lower and Middle Triassic</td>
<td>Moenkopi formation</td>
<td>30-250</td>
<td>Reddish-brown thin- and even-bedded ripple-marked beds of limy micaceous siltstone which weather to low-angle rubble-covered slopes; in places massive sandstone beds form small cliffs that rarely weather to rounded forms.</td>
</tr>
<tr>
<td>De Chelly sandstone</td>
<td>Permian</td>
<td>Cedar Mesa sandstone</td>
<td>315</td>
<td>Gray-red parallel-bedded nodular-weathering micaceous siltstone with some interbedded lenses of sandstone; forms benches; locally, basal part of formation is massive; quartz is major constituent.</td>
</tr>
<tr>
<td>Organ Rock tongue</td>
<td>Permian</td>
<td>Cedar Mesa sandstone</td>
<td>650-700</td>
<td>Orange-brown crossbedded fine- to medium-grained sandstone with thin beds of lavender, blue, gray, and green-white micaceous siltstone and shale near top and bottom; also contains discontinuous thin blue-gray limestone lenses.</td>
</tr>
<tr>
<td>Halgaito tongue</td>
<td>Permian</td>
<td>Cedar Mesa sandstone</td>
<td>400</td>
<td>Dark-reddish-brown siltstone and silty shale with thin discontinuous beds of nodular-weathering gray limestone.</td>
</tr>
</tbody>
</table>

**FROM:** WITKIND AND THADEN, 1963

**FIGURE 3.6**
COLUMNAR SECTION OF CONSOLIDATED SEDIMENTARY STRATA EXPOSED IN THE MONUMENT VALLEY SITE AREA

**LOCATION OF SITE**
and Navajo Counties, Arizona. These studies included detailed mapping of the area of the Monument No. 2 mine, which also includes the area of the Monument Valley UMTRA Project site. Results of these studies were published as Bulletins in the U.S. Geological Survey (Witkind, 1956; Witkind and Thaden, 1963) and served as the primary source of published geologic data for this study.

The position of the tailings relative to bedrock and surficial units is shown diagrammatically in Figure 3.7. The tailings are distributed in two separate areas, referred to as the old and new tailings piles for this study (not shown separately on Figure 3.7). The old 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. Although 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, published mapping (Witkind, 1956; Witkind and Thaden, 1963) indicates that they may occur at the original ground surface beneath the old tailings pile. The new tailings pile, which is located just east of the old pile, overlaps from eastward tilted beds of the Shinarump onto dune sand which overlies the Monitor Butte Member of the Chinle Formation in Cane Valley Wash. The sand dune (as encountered in exploratory boreholes advanced on-site) consists of uncremented, 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.

To the west of the site, the Chinle is underlain by the Triassic Moenkopi Formation and the Permian Cutler Formation or Group. To the east, Cane Valley Wash is underlain by the successively younger members of the Chinle Formation which are, from oldest to youngest, the Shinarump, Monitor Butte, Petrified Forest, Owl Rock, and Churck Rock members. The escarpment of Comb Ridge, which flanks the wash on the east, is formed by younger units that overlie the Chinle, including the Triassic Wingate Sandstone, the Jurassic (?) Kayenta Formation, and the Jurassic Navajo Sandstone. Unconsolidated deposits of Quaternary age in Cane Valley Wash include alluvium, dune sand, and a partly stratified sand and gravel unit.

The main structural feature of the Monument Valley site region is the Monument Upwarp, a broad, flattened anticline whose south end underlies Monument Valley (Figure 3.8). The north-south-trending axis of this upwarp extends southward into Monument Valley from the Green River Desert-Cataract Canyon region of southern Utah (Baker, 1946, cited by Witkind and Thaden, 1963).
FIGURE 3.7
GENERALIZED EAST–WEST STRATIGRAPHIC CROSS–SECTION OF MONUMENT VALLEY UMTRA PROJECT SITE

FROM: FBDU, 1977
FIGURE 3.8
NAMES AND BOUNDARIES OF THE MAJOR TECTONIC ELEMENTS
OF THE COLORADO PLATEAU, MONUMENT VALLEY SITE
Comb Ridge marks the east flank of the upwarp, forming a continuous escarpment which extends more than 145 km northeast from Kayenta, Arizona, into southeastern Utah. A number of smaller folds are superimposed on this major feature, including the Organ Rock anticline, the Oljato, Agathla, and Tse Biyi synclines, and the Gypsum Creek dome.

The Monument Valley site is on the east flank of the Gypsum Creek dome. The axis of this dome, which lies about five km west of the Monument Valley site, forms a broad arc concave toward the west (Witkind and Thaden, 1963). The dome is asymmetrical with dips averaging 7° on the east flank and 3° on the west flank. It plunges to the north and south at about 1°.

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.

3.3.4 Quaternary geology and geomorphology

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

Fluvial erosion of the old tailings pile is occurring within a deeply incised channel passing through the pile and exiting to the northeast. Removal of this material during stabilization will eliminate further erosion hazards from this channel. Lateral channel migration and headward gully erosion within Cane Valley Wash south and east of the new tailings pile present potential erosion hazards to the edge of the proposed site encapsulation. 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.

No site hazards are present from processes of landslides, debris flows, soil creep, mudflows, or rockfalls. Soil shrink-swell potential is low, and no evidence occurs of frost heave or expansive soils. Soils containing large amounts of eolian materials may be subject to collapsive or dispersive conditions.

3.3.5 Seismicity and tectonics

The Monument Valley site is in the central portion of the Colorado Plateau, a stable intracontinental subplate which is
characterized by a thick cover of relatively flat lying sedimentary rock of Phanerozoic age overlying a complex Precambrian igneous and metamorphic core (Figure 3.9). 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 mm/year (Gable and Hatton, 1980). This uplift is regional in character and produces relatively little internal deformation.

A map of historical and instrumental seismicity of the southwestern United States is shown in Figure 3.10. The site is within a region which has been characterized by widely separated, low magnitude seismicity during historical times. Geologic evidence for Quaternary fault activity within the Plateau is rare.

A floating earthquake of magnitude 6.2 is recommended as the design earthquake for the Monument Valley site. This event, as defined, could occur anywhere within the Colorado Plateau physiographic and seismotectonic province.

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, free-field, peak horizontal acceleration of 0.21g. This acceleration is determined to be greater than that which would be produced by the occurrence of Maximum Earthquakes (MEs) at the closest approaches of remote, more active provinces, such as the Intermountain Seismic Belt, Basin and Range of Arizona, and the Rio Grande Rift. A detailed field investigation of the area within a 65-km radius of the site did not reveal the presence of any capable faults. The unconsolidated Holocene dune sand which may be saturated to shallow depths in the site area may liquefy during the design earthquake.

The potential for on-site fault rupture at the Monument Valley site is nonexistent based on the geologic investigations conducted for this study. There is 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 during the 1000-year design life.

3.3.6 Mineral resources

Known economic mineral deposits in the Monument Valley site region are limited to uranium and vanadium ores. Some potential for future development may exist. The ores have been found to be concentrated along linear trends which apparently represent former channels in the Shinarump Conglomerate. Production in the
FIGURE 3.9
STRUCTURE CONTOUR MAP OF THE COLORADO PLATEAU SHOWING THE MAJOR BASINS AND UPLIFTS AND LOCATION OF THE MONUMENT VALLEY SITE

(AFTER HUNT, 1956)
FIGURE 3.10
MAP OF HISTORICAL AND INSTRUMENTALLY-DETECTED EARTHQUAKE EPICENTERS OF THE SOUTHWESTERN UNITED STATES (AFTER NOAA/NGDC). EPICENTRAL COMPILATION LIMITED TO EVENTS OF MAGNITUDE $\geq 4$ AND/OR INTENSITY (IMM) $\geq V$. 

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Monument No. 2 Mine area was chiefly from a single channel, which lies about one km west of the tailings piles. A smaller channel, which has not been developed, lies to the east of the main channel and passes beneath, or near, the tailings piles. Reserves in the site area are not accurately known. Witkind (1985) indicates that ore bodies in the site area are distributed in an irregular and seemingly random fashion. Exploration by drilling along the projected channels is basically a hit-or-miss proposition. Most known ore deposits have been removed; however, the extent of remaining, undiscovered ore is not known. Therefore, the potential for future exploration and development cannot be completely ruled out. However, it does not appear to be economical at the present time.

Oil and gas have not been produced from the site area, although some production has occurred from the Mexican Hat field to the north, which also lies along the eastern flank of the Monument Uplift. Brown and Lauth (1958) state that there is a potential for oil and gas in geologic units of Cambrian, Devonian, Mississippian, Pennsylvanian, and Permian ages in the site region. Several tests have been performed in the Monument Valley region of Arizona, but have been generally unsuccessful (Witkind and Thaden, 1963).

Economic deposits of coal are not known in the site region. Coal deposits in this general region occur primarily in units of Cretaceous age that are younger than the bedrock of the site area. None of the units that underlie the site area are known to contain economic coal deposits.

Some sand and gravel deposits exist in Cane Valley, but are not of high quality. There are no potential markets for these materials within economic hauling distances.

3.4 GEOTECHNICAL

3.4.1 Subsurface investigation

The site and nearby surrounding soils were characterized by drilling 49 boreholes and excavating 31 test pits. Figures 3.11 and 3.12 show the locations of the boreholes and test pits, respectively. The lithologic logs for all borings and test pits are presented in Appendix D, Site Characterization. Of the 49 boreholes, seven holes 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.
FIGURE 3.11
LOCATION OF GEOTECHNICAL AND GROUNDWATER BORINGS AT MONUMENT VALLEY
FIGURE 3.12
LOCATION OF TEST PITS FOR BORROW AREA AT MONUMENT VALLEY
Six of the seven geotechnical boreholes (601 through 606) are to the east of the new tailings pile. The seventh hole (607) is to the north of the old tailings pile area. Continuous standard penetration tests were conducted on each hole for the first eight feet. The holes were then drilled, without sampling, to a depth of 10 feet. Standard penetration testing (SPT) was 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 which were logged through natural soil and rock, without gathering geotechnical data, were drilled by the DOE as part of the ground-water investigation. All except three of these holes are north of the new pile area. These three exceptions are borings 651, 654, and 658. These holes are northeast, east, and southeast of the new 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 ground-water investigation of the area. The holes are to the west, south, and east of the new 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 18 holes through the new tailings pile to characterize the tailings and to determine the depth of contamination. The Bendix boreholes form a grid pattern across the new tailings pile and around the perimeter of the evaporation pond. The locations of these holes are shown in Figure 3.13.

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 were excavated in nearby potential borrow areas. Five of the six test pits excavated in tailings were excavated in a grid pattern on the new tailings pile. Test pits MON01-062 through MON01-065 were along the upper portion of the sloping cone-shaped pile, while MON01-066 was at the eastern edge of the pile. Test pit MON01-061 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.
FIGURE 3.13 LOCATION OF ON-PILE BORINGS AT MONUMENT VALLEY

REF: BFEC, 1986
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.

Twenty-two of the 24 test pits used for investigation of potential borrow sites were excavated in search of a radon barrier material source. These 22 test pits were concentrated in three different potential sites: MON03, MON04, and MON05. Borrow site MON03 is approximately 1000 feet southwest of the site area and lies in a canyon incised down into the dip slope of the Yazzie Mesa. Five test pits were excavated at MON03 to depths ranging from 12 to 16 feet. Two of these test pits were sampled.

Borrow site MON04 is approximately one mile east of the site along the base of Comb Ridge. Five test pits were excavated and four were sampled at this site. Total depths of the pits ranged from five to 12 feet.

Borrow site MON05 is approximately one mile northeast of the site along the west side of Cane Valley. Eleven test pits were excavated and seven were sampled at this site. The total depths of the test pits ranged from seven to 16 feet.

Test pits MON02-010 and MON02-01, which are the only sites sampled for erosion protection material, are actually two separate locales. Sandstone samples of the Shinarump Formation were collected from each. These two locales are along the dip slope of Yazzie Mesa, approximately three miles north of the mine site and adjacent to the sandstone bedrock - Cane Wash alluvium contact. Test pit MON02-008 is a single test pit excavated on the old airplane runway northeast of the site. The total depth of this test pit was three feet.

3.4.2 Foundation soils

The soils underlying the site at Monument Valley generally consist of fine-grained, unconsolidated dune sand with isolated zones of fine-grained silty clay and clayey sand alluvium. Geologic cross-sections of the site are shown in Figures D.3.10 and D.3.11. 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 comprised of the Shinarump Member of the Chinle Formation outcrops along the west side of Cane Valley and, where not mantled by a thin veneer of dune sand and perhaps tailings material, 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 comprised of approximately 14 feet of coarse tailings materials. Under these tailings, the small wash is filled with dune sand deposited in the wash by wind and intermittent stream...
flow to depths in excess of 80 feet. The lower, new 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 known for these deposits as they either do not underlie any of the areas of importance to this study, are not thick enough, or are of no significant areal extent. Appendix D, Site Characterization, Section D.4, discusses the engineering properties of the foundation materials.

3.4.3 Tailings

Materials forming tailings can generally be put into one of three categories: sand, sand-slime mixture, and slime. The limits for these materials are set at zero to 30 percent passing the No. 200 sieve for the sand, 30 to 70 percent for the sand-slime mixture, and 70 to 100 percent for the slime. Using these criteria, the laboratory tests were used to classify the Monument Valley tailings into one of the three categories. The processing practices at this site yielded tailings characterized as homogeneous fine- to medium-grained sand tailings with little or no slimes fraction. The top three feet of the pond area contains 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. Appendix D, Site Characterization, discusses the engineering properties of the tailings material. Only remolded tests were performed on the tailings material since it is assumed that the pile will be reworked during deep dynamic compaction, which may be necessary for foundation stability against liquefaction (see discussion in Section 4.3.6). In addition, if in-situ parameters are required, these parameters can be derived from empirical relationships incorporating SPT blow counts, which are discussed in Appendix D, Site Characterization, Section D.6.

3.4.4 Radon barrier material

Borrow areas for the radon barrier materials are all within five miles of the site in the Cane Valley area, as shown in Figure 3.12. Materials identified for sample collection and laboratory analysis included the Petrified Forest Member of the Chinle Formation and dune sand.
The potential radon barrier material borrow sites have been labeled MONO2, MONO3, MONO4, and MONO5. Site MONO2 was characterized by test pit MONO2-008. This test pit sampled the soils from the old airplane runway, approximately 700 feet north of the site. The depth of excavation was three feet. This test pit showed the first 0.5 foot to be a low plastic, dark reddish-brown clayey silt which was probably brought in for construction of the runway and is, therefore, of limited quantity. The lower 2.5 feet is composed of fine to very fine, non-plastic, light reddish-brown silty sand.

As previously described in Section 3.4.1, borrow site MONO3 is approximately 1000 feet southwest of the site, and lies in a canyon incised down into the dip slope of the Yazzie Mesa. The canyon has been partially filled with alluvial deposits of fine-grained silty sand materials which underlie a large sand dune approximately 30 feet high. Samples and logs from the test pits at the site indicate that the material is a fine-grained silty sand with occasional poorly graded, fine-grained sand and fine to coarse gravels. This material is found to the depth of excavation, which averages 14 feet for the five test pits. Due to the sandy nature of these materials, this area is considered unsuitable as a radon cover material source.

Borrow site MONO4 is approximately one mile east of the site along the base of Comb Ridge. Material from this borrow source consists of very fine-grained silty and sandy clays and fine-grained silty sand from the Petrified Forest Member of the Chinle Formation. The four test pits excavated along Comb Ridge indicate these silty and sandy clays are generally continuous to the average refusal depth of seven feet. These clays may be occasionally interrupted with a layer of silty sand. Another test pit (no. 44) excavated 3000 feet west of Comb Ridge indicates fine-grained sand and silty sand is the predominant material and extends to at least 10 feet, which is the depth of excavation. The clayey nature of this area makes it the most suitable of all areas excavated as a radon cover.

Borrow site MONO5 is approximately one mile northeast of the site along the west side of Cane Valley. This site consists entirely of stabilized fine-grained silty dune sand to a depth of at least 16 feet, the average depth of excavation. This site is considered unsuitable for obtaining radon cover material. Engineering properties of these borrow materials are discussed in Appendix D, Site Characterization, Section D.5.

3.4.5 Contaminated material

Prior to placement of the radon barrier, any windblown tailings and fine-grained material from the evaporation pond area will be placed on the pile. The quantity of windblown material is expected to be minor. In addition, due to the limited size of the
evaporation pond area and an expected contamination depth of approximately three feet, the amount of contaminated material from this source is also expected to be minor. The engineering properties of the windblown tailings are expected to be similar to those of the piled tailings, which are described in Appendix D, Site Characterization, Section D.6. The engineering properties of the evaporation pond material are also described in the tailings discussions of Appendix D, Section D.6.

### 3.4.6 Erosion-protection material

Only one borrow source was investigated specifically for use at the Monument Valley site. This borrow site has been labeled MONO2. A second erosion-protection material source has been identified near Alhambra Rock, which is also being considered for use at the Mexican Hat site.

As stated in Section 3.4.1, MONO2 is actually two locales and is located along the dip slope of Yazzie Mesa, approximately three miles north of the mine site and adjacent to the sandstone bedrock - Cane Valley Wash alluvium contact. The northernmost locale of MONO2 is a previously established borrow site. The rock at each locale is a fine-grained, moderately weathered, moderately cemented, light yellowish-brown sandstone of questionable quality for use as erosion-protection material. In addition, test pit MONO3-020 also contains occasional gravels and cobbles from a depth of two feet to the limits of test pit excavation. Although the material from MONO3-020 may appear suitable as to size, the quantity of the gravels and cobbles appears insufficient based on the logs.

The source identified near Alhambra Rock is approximately two to three road miles west of the Mexican Hat processing site (20.2 road miles from the Monument Valley site) and just north of Utah State Highway 47 (Figure 3.14). This source is a layer of very hard, dense, nonfossiliferous blue-gray limestone exposed over a large areal extent. Field observation along an arroyo indicates the thickness of this layer varies between five and 30 feet. This material is considered suitable for use as erosion protection.

### 3.5 GROUND WATER

Existing ground-water conditions at the Monument Valley tailings site and the proposed borrow sites are summarized in this section. Detailed analyses of the ground-water data are presented in Appendix D, Site Characterization, Section D.7, Ground-Water Hydrology.

The DOE collected hydrogeologic field data at the Monument Valley site in 1984 and 1985. Thirty-two monitor wells were installed and lithologic, ground-water, and water-quality data were collected.
FIGURE 3.14
BORROW LOCATION, EROSION PROTECTION
The major stratigraphic units at the Monument Valley site, from the surface down, are alluvium and dune sand, the Shinarump Member of the Chinle Formation, the Moenkopi Formation, and the DeChelly Sandstone Member of the Cutler Formation. The alluvium, the Shinarump, and the DeChelly Sandstone are aquifers. The Moenkopi is an aquitard which separates the Shinarump from the underlying DeChelly Sandstone.

Alluvium and dune sand are intermixed in Cane Valley. They are hydraulically connected, and are considered to be one stratigraphic unit. The alluvium is absent on Yazzie Mesa and thickens toward the center of Cane Valley with an average thickness of 75 feet. Alluvial ground water flows from south to north under a hydraulic gradient of 0.01. The average linear velocity in the alluvium is 29 to 42 feet per year. Alluvial ground water is unconfined with depths ranging from two to 45 feet below land surface.

The Shinarump Member of the Chinle Formation consists primarily of coarse-grained sandstone and conglomerate, and ranges from 25 to 90 feet thick in the vicinity of the tailings. The Shinarump outcrops on Yazzie Mesa, dips to the east, and is buried under alluvium in Cane Valley. Ground water in the Shinarump flows from south to north under a hydraulic gradient of 0.01, with an average linear velocity of 35 to 58 feet per year. The Shinarump is dry on Yazzie Mesa and is saturated below the alluvium in Cane Valley.

The DeChelly Sandstone is a pale-red fine-grained sandstone which is approximately 550 feet thick in Monument Valley (Witkind and Thaden, 1963). DeChelly ground water flows from south to north under a hydraulic gradient of 0.013. The average linear velocity in the DeChelly Sandstone is seven to 14 feet per year. The depth to water on Yazzie Mesa is greater than 150 feet, while DeChelly wells completed in the valley are flowing wells.

Water quality

The background water quality in all three of the aquifers is good. None of the EPA primary drinking water standards were exceeded in the upgradient wells (see Section D.7.2 of Appendix D, Site Characterization). The EPA secondary standard for total dissolved solids was exceeded at one background alluvial well. The secondary standard for manganese was exceeded in two background Shinarump wells, and the secondary standard for iron was exceeded in one background Shinarump well. Concentrations did not greatly exceed the secondary standards and do not render the water unpotable. The primary standard for gross alpha was exceeded at one background Shinarump well. This well should not be used as a drinking water source.

The only aquifer that has been appreciably impacted by the abandoned mill tailings is the alluvial aquifer. Downgradient of the tailings, nitrate concentrations exceeded EPA primary drinking water standards and sulfate concentrations exceeded secondary standards. Nitrate and sulfate plume maps for the alluvial aquifer are shown in...
Figures 3.15 and 3.16. Uranium concentrations also exceeded the recommended limits of 0.015 mg/l at some wells downgradient of the tailings.

No current water users have been affected by the ground-water contamination. All water wells in the valley are either upgradient of the tailings or well beyond the extent of the contamination. These water users will not be impacted by the tailings in the future.

3.6 SURFACE WATER

The Monument Valley site is located about 1500 feet west of the Cane Valley Wash, an ephemerally flowing stream that drains into Gypsum Creek and subsequently into the San Juan River. There are no perennial surface waters closer than the San Juan River, located at 15 miles to the north and nearly 1000 feet in elevation below the Monument Valley site.

The Cane Valley Wash drains an area of approximately 90 square miles. A Probable Maximum Flood (PMF) analysis conducted for this drainage area calculated the peak flow at 80,000 cubic feet per second.

The old tailings pile and the heap leach pads are located in a wash which drains an area of approximately 1000 acres and discharges onto the floor of Cane Valley. The arroyos south of the tailings pile drain an area of approximately 800 acres and are tributary to the west segment of Cane Valley Wash. Flood flows in washes are not recorded and water quality records do not exist.

Four small seeps have been identified along Cane Valley Wash and appear to be surface discharges of shallow ground water. Since these are hydraulically connected to the ground water, they are discussed in Section D.7 of Appendix D, Site Characterization.
FIGURE 3.15  NITRATE PLUME, MONUMENT VALLEY SITE
FIGURE 3.16  SULFATE PLUME, MONUMENT VALLEY SITE
4.0 SITE CONCEPTUAL DESIGN

4.1 INTRODUCTION

The main objective of the site conceptual design is to show that there is a design that meets the requirements of PL95-604 and the EPA standards. This section of the draft Remedial Action Plan (RAP) describes the conceptual design of the proposed remedial action at the Monument Valley tailings pile. The detailed final design will be contained in the final RAP. The specific objectives of the conceptual design of the proposed remedial action described in this section are:

- To provide interested parties with a description of the proposed remedial action plan.
- Demonstrate that the proposed design will be able to meet the EPA standards.
- To provide the criteria that will govern preparation of the final design.
- To provide the basis for the DOE to contract with the RAC to compile the detailed design.

This chapter of the report is divided into four sections. The first is this introduction. The second is a description of the proposed remedial action. The third part is a description of the various design elements of the remedial work that will be undertaken to stabilize the tailings. It is divided into sections that describe: the proposed conceptual design; the rationale for the design; alternatives considered and rejected; design criteria; and design instructions. The fourth part is a description of the construction requirements of the remedial action.

This section of the report is to be read in conjunction with the following appendices and addenda that provide more detailed information than is given in this section: Appendix B, Engineering Design, and Appendix D, Site Characterization.

The final RAP will contain the description of the final design. Appendix D, Site Characterization, will be updated to include additional information about the site obtained in the course of the final design.

The conceptual design presented in this report demonstrates a concept that meets the requirements of PL95-604. Although the final design may vary, the basic concept presented in this document represents the remedial action. Some elements of the design have not been fully developed and are intended for completion during the final design phase.

The conceptual designs and criteria are developed using the information available at the date of compilation of this report and do not represent all the data required for the design of the remedial work. Additional data will be collected during the detailed design phase and will be incorporated into the final RAP.
4.2 DESCRIPTION OF THE PROPOSED REMEDIAL ACTION

Figure 4.1 shows the present layout of the old and the new piles. The old pile is in a wash just below the now demolished mill site. The old pile covers about two acres and is about two feet deep. It is deeply incised from the flow of water from the upland watershed across the tailings. To the east is the new pile, which is conical and about 65 feet high with a radius of 500 feet and sideslopes of about five to one.

The proposed conceptual design calls for the relocation of the tailings from the old pile and other contaminated materials to the new pile. (Figure 4.3 shows the proposed layout of the stabilized pile.) When the tailings from the old pile and the contaminated materials are placed, the pile will be shaped to provide positive drainage off of the pile.

Figure 4.2 is a typical cross-section of the pile. This shows that a radon barrier of compacted, low permeability soil will be placed over the entire pile in order to inhibit both infiltration of water to the tailings and the emanation of radon gases from the tailings. The minimum thickness of the radon barrier will be one foot; the actual thickness will be determined during the final design.

Over the radon barrier are layers of filter material overlain by larger erosion resistant rock. The rock prevents water and wind erosion of the radon barrier and the tailings. The filter provides a transition between the larger rock of the erosion barrier and the fine-grained material of the radon barrier and will prevent erosion of the radon barrier.

To protect the pile from erosion around the perimeter, an apron of durable rock will be placed around that part of the perimeter of the pile which is not underlain by bedrock (as occurs on the south of the pile). Beyond the apron, the surrounding terrain will be graded to direct flow away from the pile.

All areas excavated and disturbed, and also all borrow areas, will be regraded and recontoured to promote positive drainage. Areas other than the final stabilized pile will be released for unrestricted use upon completion of the remedial action.

4.3 DESIGN DETAILS

4.3.1 Introduction

This section provides details of the major components of the proposed conceptual remedial action design. The rationale for the design is discussed and design criteria are established. For components requiring design work, alternatives considered and rejected are covered and the choice of the design detail is justified. Work to be done by the Remedial Action Contractor (RAC) in formulating the final design is listed.
FIGURE 4.2
TYPICAL CROSS-SECTION, MONUMENT VALLEY SITE
4.3.2 General requirements

Codes and standards

The detailed design to be compiled by the RAC shall comply with the EPA standards and all requirements applicable to the UMTRA Project. In addition, the detailed design shall comply with all the criteria, methods, and approaches set out in the Technical Approach Document (DOE, 1985c) and the Standard Review Plan (NRC, 1985).

In the event of a conflict between the two documents, the DOE shall issue a ruling as to which shall prevail, and this will be the standard adopted by the RAC.

Implementation procedures

The design shall be carried out in accordance with procedures set out in the UMTRA Project Design Procedures Document (DOE, 1985d).

4.3.3 Pile location

Conceptual design

As described in Section 4.2, the conceptual design calls for stabilization in place at the new pile. This involves relocating the tailings from the old pile to the new pile. The other contaminated materials at the site will also be incorporated at the new pile.

Design rationale

Stabilization in place is selected because it is the most economical option, and one which has the same or lesser environmental impact as other possible options that involve other locations.

Alternatives considered and rejected

Relocation of the tailings to the Mexican Hat pile is rejected because of the greater cost.

Relocation to a site close to and south of the present piles is also more expensive than the preferred option.

Stabilization at the old pile is not technically feasible because of:
The presence of a deep (at least 90 feet) buried arroyo beneath the pile. Differential settlement of the sands and silts in the buried arroyo could compromise the integrity of a stabilized pile at that site, by inducing cover cracking.

The location of the pile in a wash. It would be difficult and expensive to protect the tailings from erosion by water flowing down the wash and over the pile.

In addition, the greater volume of tailings is at the new pile (700,000 as compared to 250,000 cubic yards). Hence it is more cost effective to move the smaller volume of the old pile and the other contaminated materials to the new pile.

**Design criteria**

The design criteria applicable to the choice of the pile location are economics and environmental impact. Also the chosen site is able to deal effectively with the flow of water off of and away from the pile.

**Design instructions**

The RAC is to provide the most economically feasible design for a stabilized pile at the location of the new pile, and to provide for the relocation of the tailings from the old pile and contaminated materials to the new pile.

**4.3.4 Pile layout**

**The conceptual design**

Figure 4.3 shows the conceptual layout of the stabilized pile. The top of the new pile will be relocated to the west to provide for foundation stabilization (see Section 4.3.6). A roughly conical shape will be constructed with tailings from the old pile and the other contaminated materials. The entire pile will be covered with a radon barrier (see Section 4.3.11) and an erosion protection layer (see Section 4.3.12). A rock apron, composed of the same material as the erosion protection layer, will extend about 15 feet beyond the toe of the pile (see Section 4.3.12).

**Design rationale**

The shape of the proposed pile layout extends to the west side of the new pile mainly because this is the closest position to the major volumes of contaminated materials, hence the
transport distances are shortest. This also provides the volume of material needed to provide for positive control of drainage around the west side of the pile. (Further details of surface hydrology are given in Section 4.3.9.)

Alternatives considered and rejected

No other pile layouts were considered, as that adopted is considered to provide a suitable layout to meet the design requirements and standards.

Design instructions

In formulating the detailed design the RAC will:

- Provide a layout that provides for positive drainage of water off of and away from the pile.
- Provide a layout that minimizes the potential for toe erosion.
- Provide a pile layout that reduces to the maximum extent possible the cost of relocating the tailings from the old pile to the new.
- Shape the new pile tailings so that during construction it is possible to effect any required foundation stabilization.

4.3.5 Geomorphology

Conceptual design

Appendix D, Site Characterization, describes in detail the geomorphology of the area of the pile and the geomorphological processes that may operate during the design life of the pile. In particular, it is conceivable that the current course of the west segment of Cane Valley Wash may alter and flow could be established in an old meander channel that is closer to the pile than the present channel.

In order to provide for this possibility and to protect the pile, the conceptual design calls for a rock apron around part of the perimeter of the pile in order to prevent scour at the base of the pile during storm events. The apron will be a horizontal layer of erosion resistant rock at least 15 feet wide and at least three feet thick. If the wash should meander toward the pile, the apron will armor the pile against the most severe flooding conditions while maintaining the integrity of the pile.
Rationale for the design

An apron is required to protect against erosion effects in the event of channel meander toward the pile. An apron is chosen as an economical and efficient way to provide the necessary erosion protection.

Alternatives considered and rejected

Another possibility for providing erosion protection is a deep buried rock wall. This is more expensive than the rock apron because of excavation costs and is therefore rejected.

Design criteria

The design of the apron will remain stable in the event that the PMF flows past the toe of the pile. In addition, the design of the apron will be adequate to provide erosion protection at the toe of the pile in the event of the migration of the Cane Valley Wash channel during the design life of at least 200 years and, if possible, for 1000 years.

Design instructions

The RAC shall determine which method of erosion protection is most economical while providing the required protection to the pile.

4.3.6 Foundation conditions

Conceptual design details

Based on currently limited available data, analyses show that the foundation soils do not possess sufficient strength to resist liquefaction should the site experience accelerations induced by the design earthquake event. Further, more detailed characterization and analysis of this condition is required in order to quantify design parameters and corroborate the initial findings.

Preliminary analyses indicate that this condition can be rectified by using dynamic deep compaction over the entire pile foundation and for a distance of 100 feet beyond the pile perimeter. The portion of the pile which will remain in place will have its foundation densified by performing dynamic deep compaction on the pile surface. The pile will be reshaped so that it is no more than 25 feet thick prior to compaction. Total depth requiring densification below the ground surface varies from zero to less than 50 feet across the site. A minimum relative density ($D_r$) of 57 percent is required for the full depth of soil strata.
below the pile. A weight of at least 30 tons dropped in excess of 100 feet is expected to achieve the required density. Three or more passes may be required. Piezocone penetrometer (PCPT) shall be used to verify strength gains no sooner than one month following densification.

Design rationale

Foundation stability is required for the 1000-year design life of the pile. Potential problems with foundation stability include slope stability, settlement, and liquefaction. Of these, only liquefaction requires special consideration at this site. An economic analysis indicates that densification of the foundation soils is preferable to relocating the pile. Vibroflotation, replacement and compaction, and dynamic deep compaction were alternatives considered viable to densify the foundation soils. Dynamic deep compaction was chosen for reasons of economics and minimum environmental impacts.

Design criteria

- Design of the soil densification process should be based on the data available at and during the design process.
- Dynamic deep compaction should be specified unless other, more economical procedures can be found.
- A minimum 57 percent relative density is required for the full depth of foundation soils.
- PCPT in-situ density tests will be required no sooner than one month following compaction in order to verify the strength gain.

4.3.7 Seismicity

Conceptual design

A design earthquake for this site, which is in the stable interior of the Colorado Plateau, is considered to be a floating 6.2 Richter magnitude event, occurring at a distance of 15 kilometers from the site. The resulting free field site acceleration is 0.21g. Details of the studies leading to this conclusion are given in Appendix D, Site Characterization, Section D.3.

Specific seismic parameters to be used for the design are presented in the following design criteria section. These criteria were used in conjunction with appropriate soil strength parameters, pile geometry, and ground-water information in order to determine liquefaction potential and slope stability. Sections 8.2.5 and 8.3 of Appendix B, Engineering Design, provide details
of the analysis and Sections D.4, D.5, and D.6 of Appendix D, along with Section 3.4 provide design parameters and site geometry and stratigraphy used in the analyses.

Design rationale

Seismic design parameters developed for the Monument Valley site are in conformance with the DOE, Technical Approach Document (TAD) (DOE, 1985).

Design criteria

- Long-term slope stability seismic coefficient $K = 0.11$.
- Short-term slope stability seismic coefficient $K = 0.04$.
- Liquefaction analysis ground surface horizontal acceleration $a_{\text{max}} = 0.17g$.

4.3.8 Geohydrology

The following section presents a summary of the site conceptual design as it applies to ground-water protection. A more detailed discussion of the site hydrogeology and ground-water protection is presented in Appendix D, Site Characterization, Section D.7.

Conceptual design

The principal design feature for ground-water protection is a low-permeability, infiltration barrier that will cover the tailings. The current conceptual design anticipates that the cover material will be derived from the Comb Ridge borrow site. At this time it is anticipated that the cover will be approximately one foot thick. The Comb Ridge material has a saturated hydraulic conductivity of approximately 0.03 ft/yr ($3.1 \times 10^{-8}$ cm/sec). Ninety percent of the pile will have five to one sideslopes which will encourage water to run off the pile rather than infiltrate.

Design rationale

Ground-water protection at Monument Valley requires prevention of water moving through the tailings and leaching contaminants into underlying aquifers. The low-permeability cover was designed to prevent water from entering the tailings pile. The one-foot thickness of the cover required for radon entrapment (see Section 4.3.11) is also sufficient as an infiltration barrier. Under worst case saturated conditions, it will take approximately
30 years for water to pass through the cover. The long-term moisture content of the tailings will be a maximum of 10 percent. At this level of saturation, water will move through the pile at a rate of $1 \times 10^{-11}$ ft/yr (see Section D.7 of Appendix D, Site Characterization, for more detail). At this rate, it will take thousands of years for water to pass through the tailings. The combination of the low-permeability cover, the low unsaturated hydraulic conductivity of the tailings, the steep sideslopes of the pile, and the arid climate at the site indicate that the long-term flux of moisture through the tailings will be negligible. Consequently, contaminants will be prevented from leaching into the ground water.

Alternatives considered and rejected

Aquifer restoration was considered to mitigate existing ground-water contamination, and installation of a low-permeability liner was considered to prevent shallow ground water from intercepting the base of the tailings. Both of these alternatives were rejected.

Aquifer restoration is discussed in Appendix D, Section D.7. In summary, aquifer restoration was rejected for the following factors:

- Ground-water contamination has not affected existing water supplies.
- Ground-water contamination will not affect existing water supplies in the future.
- Future ground-water requirements can be met by developing alternative water supplies.
- Aquifer restoration would be technically difficult and extremely expensive relative to the minor potential benefits.

The second alternative considered was installation of a low-permeability liner below the tailings. Ground-water levels range from approximately 10 feet below the base of the evaporation ponds to greater than 30 feet below the base of the tailings throughout the western half of the pile. Although unlikely, it is possible that over a 200- to 1000-year period, water levels could fluctuate to the extent that alluvial ground water could intercept the eastern side of the tailings. If shallow ground water did intercept the tailings, additional sulfate and nitrate could be leached into the alluvial aquifer. However, due to the high cost of installing a liner relative to the potential benefits, and the factors discussed in the aquifer restoration section, no liner is necessary at this site.
Design criteria and instructions

The infiltration barrier should cover the entire tailings and should consist of material with an average hydraulic conductivity not greater than \(10^{-8}\) cm/sec. Precautions should be taken during remedial action to ensure that no more water than is necessary is introduced onto the tailings during construction. Drainage ditches should be constructed to divert surface water away from the tailings during construction. The final pile design should be completely sloped to prevent ponding of water in depressions.

4.3.9 Surface hydrology

Conceptual design

As shown on Figure 4.4 water on the pile will flow from the central part down the sideslopes to the perimeter and thereafter away from the pile.

Runoff from the 1000-acre upland watershed to the west and southwest of the pile will flow through the natural drainage to the west of the pile. Runoff from the pile and the adjacent area to the east will flow from the pile on the natural downslope. Minor recontouring of this area will be necessary to avoid flow concentration. On the north side of the site, flow will be adjacent to the pile on a new swale created as part of site grading. Runoff from the 800-acre watershed directly south of the new tailings pile will flow east of the pile in the wash which parallels Cane Valley Wash. The main segment of Cane Valley Wash is 1500 feet east of the pile. Under normal circumstances, flow in the wash does not affect the pile. However, extreme events may cause flow to approach the east perimeter of the pile.

As described in Section 4.3.12, an erosion barrier and an apron will be placed on and around the pile to protect against the erosive forces caused by the flows described above.

Further details of the surface hydrology may be found in Appendix D, Site Characterization. Details of the analyses supporting the above description of the conceptual design may be found in Appendix B, Engineering Design.

Design rationale

The pile is shaped to prevent water from ponding on the pile, reducing the potential for infiltration through the tailings and to avoid flow concentrations.

No provision is made for swales on the west as bedrock occurs at the surface and because of the high cost of cutting channels into bedrock.
FIGURE 4.4
SURFACE-WATER FLOWS
The design makes use of the existing topography with minor site regrading.

Alternatives considered

As noted above, channels or ditches in the south and west are rejected because of bedrock. Also it is less expensive and more efficient to place an erosion control apron around the pile rather than constructing.

Design criteria

The design of the pile should provide for directing water away from the pile in a way that lessens the potential for erosion of the pile during the design life. The design features should make use of the existing layout of the new pile and the surrounding topography.

Design instructions

During detailed design, the DOE will assess the impacts on the pile of the PMF in Cane Valley Wash taking into account the geomorphology study that is currently under way.

The area of the old pile will be graded so as to prevent flows from the 1000-acre watershed to the southwest from impacting the stabilized pile.

Detailed design by the RAC shall include but is not limited to:

- Detailing swales and regrading around the pile, as mentioned.
- Detailing the extent of bedrock around the southwest and west sides of the pile.
- Designing a pile layout which precludes concentrated flows.

4.3.10 Geotechnical

Conceptual design

In order to meet the 1000-year design criteria, an analysis of slope stability and settlement using material properties and critical geometries of the reclaimed pile was performed. These analyses assume that all fills placed at the site will be engineered and have material properties equal to or more conservative than assumed in the analyses. Resulting limitations placed on the design are presented in the following design criteria section.
Rock sizing and surface-water runoff control (Sections 4.3.12 and 4.3.9) are the critical factors in determining the need for five horizontal to one vertical sideslopes. Analyses show that seismic long-term stability will be the controlling condition, resulting in a factor of safety of 2.2, well above a factor of safety normally considered acceptable.

Settlement is not considered critical for long-term stability. Analyses show that 70 percent of all settlement will occur during construction due to the granular nature of the tailings and foundation soils. The remaining 30 percent of settlement amounts to 0.33 feet. Differential settlement of 0.33 feet will result in 0.02 percent strain in the cover, well below the strains that the cover system can tolerate.

**Design rationale**

Primary consideration of pile configuration resulted from restraints other than geotechnical ones. Analyses were performed in order to verify the feasibility of the conceptual design and to aid in specifying required design criteria. Procedures used in these analyses conform with the TAD (DOE, 1985c).

**Design criteria**

- Final pile configuration should address additional cover settlement and related cracking considerations, if any.
- Final pile design should analyze slope stability for sections critical to the design. Minimum allowable factors of safety required for various design conditions are presented in the TAD (DOE, 1985c). These values should be used in analyzing the final pile stability.
- The maximum percentage of organics contained within the reshaped pile should not exceed five percent by volume, distributed in a manner that will avoid pockets or layers of organic matter.
- The relocated tailings and contaminated material should be placed at a minimum of 90 percent of the standard Proctor density (ASTM D698). Due to the granular nature of compacted material, drying by moisture conditioning is not expected to be necessary.
- The radon cover should be placed at a minimum of 95 percent of the standard Proctor density (ASTM D698) and at greater than plus two percent of optimum moisture content.
Material properties used in final design should be those specified in Appendix D, Site Characterization, unless other more appropriate parameters are defined. In such cases final design calculations should provide the rationale for selecting the different design parameters.

4.3.11 Radon/infiltration barrier

This section summarizes the radiological aspects of the conceptual design of the Monument Valley uranium mill tailings site. The details of the assumptions and calculations leading to the conceptual design are contained in Appendix B, Engineering Design. The two primary areas of influence by radiological considerations are the excavation volumes of material to be stabilized and the radon barrier design to meet the EPA flux standard of 20 pCi/m²s.

Excavation volumes and embankment radium-226 profile

The limits of contamination across the Monument Valley site are estimated in Appendix D, Site Characterization. Not all contaminated material on the site will need to be excavated for the stabilization in place concept. The contaminated soils and tailings in parts of the batch leach area (Area C), along the west edge of the new pile, in the new tailings pile, and beneath the new pile will not be excavated.

In some areas excavation will likely remove more material than is estimated to be contaminated. This is expected in some parts of the ore storage/mill yard (Area E) and road berm areas. For these two reasons, the volumes of excavated material to be placed in the final embankment will differ from the volumes of contaminated material identified in Appendix D. Table 4.1 presents a summary of the extent, depth, volume, and average radium-226 content of contaminated soil to be excavated for placement in the final pile.

The general construction sequence for placing the contaminated materials in their final configuration calls for movement of 100,000 cy from the top of the existing new pile. This material would be placed immediately adjacent to the western side of the new pile. The contamination in the pond area on the eastern side of the new pile would then be excavated from an area of about 9.7 acres. Next the heap leach pad material would be evenly placed over the resulting mound. Finally, all other contamination (Areas C, D, and E and the rubble pile and roads) would be placed over the former material. All distinct layers will be placed over the entire surface of the previous layer. In all areas of excavation, it
Table 4.1 Summary of excavated materials

<table>
<thead>
<tr>
<th>Subarea/description</th>
<th>Area (acres)</th>
<th>Depth (ft)</th>
<th>Volume (cy)</th>
<th>Ra-226 (pCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of new pile</td>
<td>6.1</td>
<td>10.2</td>
<td>100,000</td>
<td>65</td>
</tr>
<tr>
<td>Pond area east of pile</td>
<td>9.7</td>
<td>3.6</td>
<td>56,090</td>
<td>174</td>
</tr>
<tr>
<td>Heap leach area</td>
<td>10.6</td>
<td>12.0</td>
<td>205,620</td>
<td>52</td>
</tr>
<tr>
<td>Area E (ore storage)</td>
<td>23.9</td>
<td>scattered</td>
<td>17,110</td>
<td>51</td>
</tr>
<tr>
<td>Area C (batch leach)</td>
<td>7.5</td>
<td>2.3</td>
<td>27,930</td>
<td>40</td>
</tr>
<tr>
<td>Area D (old pile remnant)</td>
<td>1.0</td>
<td>2.5</td>
<td>4,000</td>
<td>36</td>
</tr>
<tr>
<td>Rubble piles</td>
<td>0.2</td>
<td>1.0</td>
<td>300</td>
<td>25</td>
</tr>
<tr>
<td>Roads</td>
<td>1.5</td>
<td>1.2</td>
<td>3,000</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>60.5</strong></td>
<td></td>
<td><strong>414,050</strong></td>
<td></td>
</tr>
</tbody>
</table>

is assumed that no backfill will be applied. Table 4.2 presents the thickness of each of the layers along with the physical parameters influencing radon transport.

The radium-226 distribution in the proposed tailings embankment is based on the radioactivity of the off-pile and off-site excavated soils (as calculated in Sections B.4.1 through B.4.4 of Appendix B, Engineering Design), the radioactivity of the unexcavated soils lying within the boundaries of the embankment, and the radium distribution in the recontoured tailings pile.

In addition to the Ra-226 concentration difference, each layer also has an independent set of physical properties which affect radon transport. These properties include diffusion coefficient, emanating fraction, porosity, bulk density, and moisture content. Each of these parameters for the four layers is presented in Table 4.2.

**Radon barrier**

The minimum thickness of the proposed radon barrier is one foot. This is the value required to reduce the flux of radon to the applicable EPA limit of 20 pCi/m²·s. The radon flux through this cover is expected to average less than 15 pCi/m²·s above background. The calculations are based on information presented in Appendix D, Site Characterization, and Appendix B, Engineering Design.
**Table 4.2** Summary of final pile layers

<table>
<thead>
<tr>
<th>Layer material description</th>
<th>Volume (cy)</th>
<th>Thickness (feet)</th>
<th>Average Ra-226 concentration (pCi/g)</th>
<th>Long-term moisture (%)</th>
<th>Diffusion coefficient (cm²/s)</th>
<th>Emanating fraction</th>
<th>Porosity</th>
<th>Bulk density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas C, D, and E and rubble and roads</td>
<td>52,340</td>
<td>1.8</td>
<td>43</td>
<td>5</td>
<td>0.0286</td>
<td>0.29</td>
<td>0.36</td>
<td>1.77</td>
</tr>
<tr>
<td>Heap leach pads</td>
<td>205,620</td>
<td>7.1</td>
<td>52</td>
<td>5</td>
<td>0.0286</td>
<td>0.29</td>
<td>0.36</td>
<td>1.77</td>
</tr>
<tr>
<td>Pond area</td>
<td>56,090</td>
<td>3.9</td>
<td>174</td>
<td>5</td>
<td>0.0285</td>
<td>0.29</td>
<td>0.56</td>
<td>1.26</td>
</tr>
<tr>
<td>New pile</td>
<td>653,890</td>
<td>45.9</td>
<td>65</td>
<td>2</td>
<td>0.048</td>
<td>0.23</td>
<td>0.43</td>
<td>1.54</td>
</tr>
</tbody>
</table>
The proposed structure of the pile has six components: (1) the recontoured new tailings pile and unexcavated peripheral contamination along the eastern half of Area C (batch leach area); (2) a layer of contaminated material from the pond area; (3) a layer comprised of material from the heap leach pads; (4) a layer made up of all other contamination on the site; (5) the radon barrier cover; and (6) a rock and gravel erosion protection layer. The erosion protection layer is ignored for radon barrier design.

The proposed material for the radon barrier is from the Comb Ridge borrow site. This is the only suitable cover material in the vicinity of the Monument Valley site. A single cover configuration was considered in the design of the stabilized embankment. This is due to the poor diffusion coefficient and long-term moisture content retention properties of the vast majority of available materials. The cover material from the Comb Ridge borrow site is near the site and exists in quantities sufficient for the cover required.

Based on the properties of the stabilized layers summarized in Appendix B, Engineering Design, the required thickness of the cover to bring the average flux from the cover surface down to 20 pCi/m²s is 0.7 foot (21 cm). This is conservatively rounded up to the nearest half foot to a proposed thickness of one foot. This is somewhat smaller than typical covers required for other sites in the UMTRA Project. Contributing to the requirement for a thin cover is contaminated material which is relatively low in Ra-226. In addition, the cover material is estimated to have a relatively high long-term moisture content (18 percent). At a thickness of one foot, the proposed cover actually reduces the flux to less than 15 pCi/g.

The cover design for the pile is intended to give a long-term annual average flux of 20 pCi/m²s. However, some conservative assumptions are implicit which indicate the actual flux should, in fact, be less.

The design moisture content of the pile is intended to be the driest long-term moisture content maintained by the pile materials considering climate, the consistency and compaction of the material, and the depth of the material in the pile. To the degree the actual moisture content remains above the design moisture content, the actual flux will be less than the design flux.

Any periods of harsh winter will add an additional degree of safety not reflected in the design. Whenever the soil is very wet, frozen, or covered with snow, the radon is effectively blocked from escaping into the atmosphere. Depending on the period over which such conditions exist, there will be a reduction in the actual annual average flux as compared to the design flux.

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In the design of the pile, no radon flux attenuation was attributed to the rock and gravel cover that will be applied to the pile as erosion protection. There is some decrease in the radon flux due to this cover; thus a safety factor is present. Since the erosion protection is designed to withstand extreme erosive events, it is likely that its contribution to radon flux reduction will persist for an extensive period of time.

No safety factors are intentionally applied in the design of the radon barrier, which is in agreement with the design nature of the radon flux standard as expressed by the EPA in its comments on the basis of the regulations. It is the intent of this discussion to make clear that there are reasons to expect that the annual average flux measured around a stabilized pile would be lower than the design flux.

The stabilization in place option for the Monument Valley site requires placing off-pile materials on the recontoured tailings pile. The following assumptions affected the radon barrier design:

- It will be possible to place contaminated soils excavated from the pond area and heap leach pads as two layers on the recontoured tailings, and to place contaminated soils from Areas C, D, and E and rubble and road areas as an outer layer.

- Heap leach pad average values of the radon emanating fraction are suitable for describing material from the pond area and Areas C, D, and E and rubble and roads.

- Values of the radon diffusion coefficient determined from the heap leach pad samples are suitable for describing contaminated soils from Areas C, D, and E and rubble and roads.

- It will not be necessary to move the base of the existing new tailings pile or any sub-pile contaminated soil, since this area will be covered by the stabilized pile.

- The available cover materials are adequately represented by the borrow samples obtained for geotechnical and diffusion coefficient analyses.

- The average moisture contents for the stabilized pile and cover, as predicted by engineering analyses, are suitable estimates of the long-term average condition of the pile.
The compaction and placement of the tailings, other contaminated materials, and cover soils are sufficient to inhibit settlement and cracking of the cover.

4.3.12 Erosion barrier

Conceptual design

Rock erosion protection will be placed over the radon barrier, and will be extended to an apron around most of the pile perimeter.

The erosion protection will consist of a filter layer overlain by a durable rock layer. The filter materials will come from designated sources within approximately three miles of the site. The durable rock will come from the Alhambra Rock borrow source approximately 21 miles north of the site.

The filter materials will have a gradation that prevents possible erosion or piping of the radon barrier through the overlying larger rocks. The filter layer thickness will be at least six inches. The rock layer will be about one foot thick, with an anticipated average rock size (D50) of four inches.

The apron will extend about 15 feet out from the pile and around that part of the perimeter where bedrock is not exposed. The thickness of the apron will be approximately three feet below grade.

Section D.5 of Appendix D gives details of the borrow sources for erosion protection materials. The properties of possible erosion resistant rock are described in that section. The calculations and supporting discussions on the choice of rock size and layer thickness for the erosion barrier for the conceptual design are given in Section B.8 of Appendix B, Engineering Design.

Design rationale

The purpose of the apron is to protect the pile from the erosive forces of the PMF that could cause undercutting in the relatively soft soils adjacent to the pile.

A layer of filter material and erosion resistant rock is placed over the radon barrier in order to protect the radon barrier from erosion by water from both normal and extreme precipitation events, and hence provide for the integrity of the pile.
Alternatives considered and rejected

Rock is selected in preference to a vegetated soil layer because the area is arid and vegetation is not easily established. A dense stand of vegetation is unlikely to persist through the design life of the pile, and an uneconomically thick layer of unvegetated soil would be required.

An apron is selected in preference to a buried rock wall or a ditch as the apron is more economical and has less of an environmental impact during construction.

Design criteria

The erosion barrier over the pile will be designed to resist the forces of erosion resulting from the PMP on the pile and the PMF in the surrounding area. The rocks used shall be durable according to the requirements of the TAD. The filters shall also be designed as described in the TAD (DOE, 1985c).

Design instructions

The RAC in formulating the final design shall:

1. Confirm the required rock size on the pile and for the apron.
2. Confirm filter layer thickness and gradations.
3. Verify the suitability of the apron instead of a buried rock wall.

4.4 CONSTRUCTION

4.4.1 Introduction

The procedure to be adopted to implement the remedial action depends on the details of the final design. The RAC is responsible for the final detailed design and the remedial action. Upon completion of the detailed design, a description of the construction activities will be incorporated into this section of the final RAP.

The following is a statement of design intentions, criteria, and instructions. It may also be viewed as a brief overview description of what construction activities may actually take place.
4.4.2 Overview

A staging area will be developed. Decontamination facilities will be located at or near the entrance to the site.

Temporary ditches or swales will be constructed in order to prevent uncontaminated runoff from entering the site during remedial action construction. Collection ditches will channel contaminated runoff to a waste-water retention pond or ponds for evaporation or use in compaction or dust control in contaminated areas.

A site security system will be established. A construction fence will provide control of the traffic entering and leaving the site, and will prevent unauthorized traffic from entering the area.

4.4.3 Drainage, erosion control, and waste-water retention basin

During remedial action construction, all contaminated drainage from the site will be contained. Contaminated disturbed areas will be graded so that runoff drains to a waste-water retention basin. Cleaned disturbed areas can be graded to divert uncontaminated runoff away from contaminated areas.

Waste-water ditches will be designed to carry the peak flow amount resulting from a 10-year one-hour storm event. Diversion ditches will also be sized to carry the peak runoff flows from a 10-year 24-hour storm event, and will serve to prevent uncontaminated runoff from entering the site.

Location and design of the waste-water retention basin(s) and collection ditches will be determined during final design.

The waste-water retention basin(s) will receive waters resulting from:

- Runoff over contaminated areas.
- Processing site dewatering, if required.
- Decontamination activities including equipment and truck washdown.
- Laundry, shower, and washbasin facilities.

The retention basin at the site will be designed to retain the runoff resulting from a 10-year 24-hour storm event as well as waste waters generated from the remedial action activities. The retention basin additionally shall have sufficient capacity to hold all sediment inflow during the project life without need for removal. The emergency outlet from the basin will be designed to safely discharge the peak 25-year one-hour storm runoff while one
foot of freeboard is maintained between the top of the embankment and the water surface with the emergency spillway flowing at design depth.

4.4.4 Demolition

No contaminated material will leave the site. Concrete foundations and site rubble will be demolished only if necessary for burial.

4.4.5 Equipment decontamination pad

To prevent contaminated materials from being carried out of the construction areas, a decontamination pad with a holding pond and recirculating pump will be provided at the site to wash contaminated equipment.

4.4.6 Dust control

Dust generated by excavation, earth movement, vehicle use, temporary materials stockpiling, and similar activities will be controlled and minimized by the use of water and water-based surfactants sprayed from hoses or trucks. Special care will be taken to control dust created by building decontamination or demolition and the temporary stockpiling or mixing of contaminated materials.

The sources for dust suppression water will include recycled water from the waste-water retention basin. Only uncontaminated water will be used for the clean areas.

The schedules for spraying the roads and pile areas will vary daily and will be determined on an hour-by-hour basis. The frequency of spraying will increase when combinations of low soil moisture and high wind speed are encountered.

4.4.7 Construction sequence

The following construction sequence is proposed as a possible sequence for the remedial action. As with the layout (Section 4.4.4), the RAC's final design will go into more detail and the construction subcontractor will be allowed the flexibility of executing his work as he chooses, given certain constraints. Therefore, the actual construction sequence may be different from the following.

Initially, a site security system will be set up and coordinated with staging and vehicle decontamination areas. This will provide control of traffic entering and leaving the site and
prevent unauthorized traffic from entering the area. Utilities, construction trailers, and associated facilities can also be mobilized or constructed at this time.

The next major item of site preparation is the construction of waste-water control structures, including retention basins, erosion control ditches, and site drainage features. Uncontaminated materials excavated during construction can be stockpiled for later use as fill, or used during embankment construction. Access and haul roads will be constructed or upgraded at this time. Concurrent with these initial activities, the building decontamination or demolition process could begin.

Following site preparation, embankment construction can begin. This will include consolidation of tailings and subsoils, shaping the embankment, and buttressing the sideslopes. The mill rubble disposal pit could be excavated and final disposal of demolished mill buildings and concrete pads could be performed.

When the tailings embankment is reshaped, the old pile tailings will be excavated, placed, and compacted in lifts over the new tailings pile.

The final stages of remedial action will involve overall site drainage grading; placement of rock cover over the pile; restoration and revegetation of disturbed areas at the site and borrow area; and construction of an access road and site designation monuments.

Demobilization will consist of removal of the staging areas, waste-water retention basin, decontamination pad, and temporary drainage ditches. Any water remaining in the basins will be treated, if contaminated, and discharged. The contaminated sediments, sludges, and the bottom and sides of the basin and ditches will be excavated and incorporated into the embankment. The decontamination area and staging area will be destroyed and all contaminated items will be either cleaned for salvage or buried. All equipment used on the site must be inspected and decontaminated before release.

4.4.8 Construction schedule

A construction schedule is presented in Figure 4.5, which shows a continuous construction effort of 10 months.

4.4.9 Preliminary cost estimate

A preliminary cost estimate based upon the conceptual design described in this Remedial Action Plan has been prepared. The conceptual design construction cost estimate is $4.13 million. The total cost estimate is $5.87 million. These cost estimates are summarized in Table 4.3.
Table 4.3 Site cost estimate summary (1985 - $000)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remedial action (RA)</td>
<td></td>
</tr>
<tr>
<td>Site preparation</td>
<td>1189</td>
</tr>
<tr>
<td>Tailings pile</td>
<td>1656</td>
</tr>
<tr>
<td>Cover</td>
<td>197</td>
</tr>
<tr>
<td>Erosion protection</td>
<td>920</td>
</tr>
<tr>
<td>Decontamination facilities</td>
<td>52</td>
</tr>
<tr>
<td>Restoration</td>
<td>120</td>
</tr>
<tr>
<td><strong>TOTAL PROCESSING SITE REMEDIAL ACTION</strong></td>
<td><strong>$4134</strong></td>
</tr>
<tr>
<td>Engineering</td>
<td>530</td>
</tr>
<tr>
<td>Field management</td>
<td>1103</td>
</tr>
<tr>
<td><strong>TOTAL ENGINEERING/FIELD MANAGEMENT</strong></td>
<td><strong>1633</strong></td>
</tr>
<tr>
<td><strong>SURVEILLANCE AND MAINTENANCE</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td><strong>TOTAL PROCESSING SITE COST ESTIMATE</strong></td>
<td><strong>5867</strong></td>
</tr>
</tbody>
</table>
### FIGURE 4.5 REMEDIAL ACTION SCHEDULE, MONUMENT VALLEY SITE

<table>
<thead>
<tr>
<th>ACTIVITIES</th>
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<td>TAILINGS RELOCATION</td>
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<td>SITE RESTORATION</td>
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5.0 ENVIRONMENTAL, HEALTH, AND SAFETY

5.1 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 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 to prevent accidents and radiation exposure. The RAC will prepare a site-specific Environmental, Health, and Safety Plan which meets the requirements of the UMTRA Project Health and Safety Plan (DOE, 1985a). The site-specific Environmental, Health, and Safety Plan will be available for NRC and state/tribal review prior to its field implementation.

5.2 SITE CONDITIONS AFFECTING HEALTH AND SAFETY PLANNING

The remedial actions at the Monument Valley site will require special attention to potential hazards because of the wide range of activities that were conducted at the site during its operation, the various toxic and hazardous materials which may remain at the site, and the physical hazards which exist at the site. This section describes those specific conditions which are known or suspected to exist at the site, and which will require special attention in the site-specific health and safety plans to be developed by the RAC.

At the site, there are no structures still standing or known utilities. The Monument No. 2 Mine sits about one mile west of the processing site atop the Yazzle Mesa. While no remedial action is anticipated in the mine area, it should be noted that significant potential exists for wall and overhang collapse in the mine area. Access to the mine during construction should be controlled (or eliminated) for these reasons.

The Monument Valley site is located in a remote area with no commercial utilities present. It is accessible only by dirt road. Emergency medical facilities (over and above those normally employed) should be present on the site during construction to preclude transporting injured personnel. The nearest hospital with 24-hour emergency service is the Monument Valley Adventist Hospital. Phone numbers for the hospital and other emergency response organizations are provided below:

-71-
Ambulance, Monument Valley
Ambulance, Mexican Hat
Monument Valley Adventist Hospital
Fire Department, Monument Valley
Police/Sheriff, Kayenta

(801) 727-3241
(801) 587-2237
(801) 727-3241
(801) 727-3241
(602) 697-3578
6.0 RESPONSIBILITIES OF PROJECT PARTICIPANTS

6.1 INTRODUCTION

The following defines the various responsibilities of the U.S. Department of Energy (DOE) UMTRA Project Office, the U.S. Nuclear Regulatory Commission (NRC), the Navajo Nation, and the Bureau of Indian Affairs (BIA) during design, remedial action, and through the initiation of custodial surveillance and maintenance. The DOE will be assisted by its Technical Assistance Contractor (TAC), the Jacobs-Weston Team, and Remedial Action Contractor (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, and the BIA 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 surveillance and maintenance plan.
- Certify remedial action.
- Obtain license.
- Conduct surveillance and maintenance.

Navajo Nation:
- Review and concur in the Remedial Action Plan (RAP).
- Assist the DOE in acquiring or extinguishing the interests of landowners or others with property interests at the designated processing and disposal site.
- Assist in obtaining local government 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/SCD.
- Review and concur in surveillance and maintenance plan.
Review and concur in final certification report.
Issue a license for long-term surveillance and maintenance of
the disposal site.

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

6.2 DETAILED RESPONSIBILITIES

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

6.2.1 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 appro-
priate 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.

6.2.2 Licensing

As part of the licensing task and prior to completion of the
remedial action, the DOE will prepare a draft license application
including site surveillance and maintenance plan. 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).

6.2.3 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 land withdrawal agreement for the long-term surveillance and maintenance of the site by the Federal Government.

6.2.4 Detailed design

The RAC will prepare preliminary engineering drawings for review by the DOE. Based upon this review, the RAC will prepare final design drawings, specifications, and bid packages. Once finalized 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 will be available to the NRC and the Navajo Nation upon request.

6.2.5 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, 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.

6.2.6 Health and safety

The DOE will prepare a site-specific Environmental, Health, and Safety Plan in conformance with the UMTRA Project Environmental, Health, and Safety Plan (DOE, 1985a). Based upon this guidance, site-specific implementation procedures will be developed by the RAC. As part of the implementation procedures, 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.

6.2.7 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).

6.2.8 Radiological support

The DOE will prepare and implement a Radiological Support Plan (Appendix C) and will take measures to independently assure 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.
6.2.9 Quality assurance

The DOE will prepare the Quality Assurance (QA) Plan in conformance with guidelines established in the UMTRA Project QA Plan (DOE, 1983). The DOE will audit the construction activities and will submit audit reports as appropriate.

6.2.10 Surveillance and maintenance

The DOE will prepare and submit to the NRC the Site Surveillance and Maintenance Plan 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.
7.0 SURVEILLANCE AND MAINTENANCE

7.1 INTRODUCTION

The objective of the custodial surveillance and maintenance program is to assure that the disposal site continues to function as designed.

The custodial surveillance and maintenance programs will be defined jointly by the DOE and the NRC during the license application and approval process. Following are the basic elements that may be included in this program.

7.2 SURVEILLANCE

7.2.1 Site inspections

Site inspections constitute visual and definitive verification that the disposal site continues to function as designed. Inspections will consist of two phases: Phase I, systematic walk-over designed to qualitatively evaluate the condition of the disposal site; and, if needed, Phase II, investigations to quantitatively assess changes in the disposal site that could lead to functional failure of the design in the absence of custodial maintenance.

The Phase I inspection will be conducted annually by a team of qualified professionals. The inspection team will review as-built drawings, engineering details, aerial photographs, and supporting documentation. A site walk-over will then be performed to evaluate any changes at the site with regard to factors such as erosion, flood effects, slope/cover stability, settlement, displacement, plant or animal intrusion, and access control.

Based upon the evaluation and recommendations of the inspection team, Phase II evaluations may be conducted to quantitatively determine the magnitude and rate of changes in the above factors. From these studies, the need for a corrective action (i.e., custodial maintenance) would be ascertained.

7.2.2 Aerial photography

Aerial photography will be used to supplement site inspections. The objectives would be to identify changes in site conditions (e.g., patterns of developing erosion that may affect the function of the design), provide visual documentation of long-term variation in site conditions, and identify activities (e.g., road conditions, storm drainage construction) adjacent to the site that may affect its function.

Photographs would be taken at both low (i.e., high resolution) and high (i.e., for adjacent activities) altitudes and...
vertical angles. The type of film, ground control, camera specifications, amount of aerial overlap, interpretative keys, and other requirements will be established as part of the custodial surveillance and maintenance program.

7.2.3 Reporting

Summary surveillance and monitoring reports that evaluate the results of these activities and recommend needed custodial maintenance (i.e., corrective actions), along with future surveillance and monitoring, will be prepared. Reports and supporting documentation will be placed on file with the DOE, NRC, and the Navajo Nation.

7.3 CUSTODIAL MAINTENANCE

The need for custodial maintenance can only be determined following site inspection. However, it is anticipated that custodial maintenance will consist primarily of the following:

- Limited soil/rock replacement due to unanticipated erosion, human or animal intrusion, or cover disturbance—these activities are expected to be required infrequently.
- Control of deep-rooted plants by infrequent application of herbicides or physical removal as required.
- Mechanical repairs to concrete posts and warning signs, when necessary.

7.4 CONTINGENCY PLANS

Procedures will be developed to inspect and perform maintenance, as required, at the disposal site upon the occurrence of severe meteorological events (e.g., extreme rainfall), seismic events in excess of design parameters, or unusual human intrusion.
8.0 QUALITY ASSURANCE

8.1 GENERAL

The Remedial Action Contractor (RAC) shall provide and maintain an effective quality assurance (QA) program and procedural system which will assure that all work, materials, supplies, and services required under the contract conform to contract requirements, whether constructed or processed by the RAC or its subcontractors, or procured by subcontractors or vendors. The RAC shall perform or have performed adequate inspections and tests as will ensure and substantiate that all work, materials, supplies, and services conform to contract requirements.

The RAC shall furnish, with the preliminary design, a QA test and inspection plan outline for the site which defines the health, safety, and environmental activities to be incorporated into the design and/or performed during construction to ensure contract compliance and site certification. Test and inspection requirements shall be submitted for approval by the DOE prior to the start of any physical job site construction work. For procurement in advance of construction, those portions of the QA plan dealing with procurement shall be submitted to the DOE for review and approval prior to placement of any purchase requisition. If the RAC revises the plan, the RAC shall concurrently furnish a copy of the revision to the DOE for approval prior to implementing the revision on work under the contract.

8.2 QUALITY ASSURANCE PLAN

Before construction operations are started, the RAC shall meet with the authorized QA representative of the DOE to review and discuss the RAC's proposed project QA plan. The meeting shall develop mutual understanding relative to details of the individual site plan requirements including the formats to be used for recording and reporting tests and inspections, administration of the plan, personnel assignments, and the interrelationship between the RAC and the DOE QA representative. The RAC shall furnish a list of the procedures required to implement the project plan. This list shall include, at a minimum, procedures for data collection, analyzing samples, inspection and testing, and formats of reports to be used.

8.3 DAILY INSPECTION REPORT

The RAC shall prepare a daily report for every day worked and a weekly summary report covering the RAC and/or subcontractor's operations in an appropriate format. These reports shall be maintained at the site until completion of work. These logs shall provide complete and factual evidence that continuous, effective, quality control construction inspections and tests have been performed, including but not limited to: (1) the type and number of inspections and tests involved; (2) results of inspections and tests; (3) nature of deficiencies requiring corrections; and (4) corrective actions taken or to be taken. The RAC shall maintain current records of all inspections and shall furnish, as part of the
files at the end of the Project, copies of the inspection reports and all other files appropriate to each individual subcontract. The reports of inspection shall cover all work placement subsequent to the previous report and shall be verified by the RAC's designated QA representative.

8.4 MEASURING AND TEST EQUIPMENT CALIBRATION AND CONTROL

The RAC shall provide measuring and test equipment having the precision and accuracy needed to establish conformance with specified quality requirements. Calibrations shall be in accordance with nationally recognized standards. The RAC shall identify procedural systems for test equipment calibration and recall.

8.5 NONCONFORMANCE

A nonconformance and change procedure system shall be developed by the RAC and approved by the DOE.

8.6 RECORDS CONTROL

The RAC shall be responsible for generation, retention, and retrieval of legible records providing objective evidence of conformance to the specified quality requirements. These records shall be considered valid only if they are completed and signed or otherwise authenticated and dated by authorized personnel. These records should include, but are not limited to:

- Radionuclides in soil data.
- Air monitoring data.
- Design review files.
- Water contaminant analysis.
- Personnel radiation exposure data.
- As-built drawings.
- Test and inspection reports.
- Engineering specifications.
- Material certifications.
- Certificates of compliance.
- Reports and corrective action requests.
- Operating procedures.

All records shall be available to the DOE for review upon request. All personnel radiation exposure records shall be turned over to the DOE upon completion of the site remedial action.

8.7 CODES AND STANDARDS

The RAC shall have on the job site, no later than three weeks after site mobilization, the applicable quality assurance codes and standards available for ready reference by all personnel. The RAC shall maintain
at the job site copies of all approved for construction drawings, specifications, and other documents which describe the remedial action.

8.8 AS-BUILT DRAWINGS

The RAC shall develop QA procedural systems to assure the use of authorized (approved for construction) drawings and specifications and the maintenance of current as-built drawings. Two full-size sets of contract drawings shall be used by the RAC for this purpose. All variations from the contract drawings shall be depicted. Generally, the drawings shall reflect only such changes and/or corrections to data and dimensions shown on contract drawings. Where the contract specifications or drawings permit optional use of more than one type of material or equipment, the type of material or equipment installed shall be shown on the drawings. The drawings shall be maintained in a current condition at all times and shall be made available for review by the DOE at all times. Variations from the contract drawings shall be shown in the contract working drawings and shall be incorporated onto the as-built drawings. Upon physical completion of the contract work, two copies of the as-built drawings shall be furnished to the DOE.

8.9 MATERIAL CERTIFICATION

The technical specifications may require that certain materials be certified. Two types of certifications may be specified:

- Certificates of compliance.
- Certified material test reports (CMTR). When a CMTR is requested from the RAC or its subcontractors, it shall be accompanied by a certificate of compliance certifying that the tested material is actually that material incorporated in the work.

8.10 QUALITY ASSURANCE PROGRAM VERIFICATION

Verification of the QA Program implementation by the DOE may be accomplished by:

- Review of daily or weekly summary reports.
- On-site inspections and surveillance.
- Periodic audits.
- Acceptance of DOE QA recommendations based on DOE QA audits of RAC activities.
- Any combination of the above.
9.0 PUBLIC INFORMATION AND PUBLIC PARTICIPATION

9.1 INTRODUCTION

Section III of the UMTRCA states,

"In carrying out the provisions of this title, including the designation of processing sites, establishing priorities for such sites, the selection of remedial action and the execution of cooperative agreements, the Secretary (of Energy), the Administrator (of the Environmental Protection Agency), and the (Nuclear Regulatory) Commission shall encourage public participation and, where appropriate, the Secretary shall hold public hearings relative to such matters in the state where processing sites and disposal sites are located."

It is the intent of the public information and public participation program to fully inform the interested public and use the feedback in the decision-making processes and remedial action activities relative to the UMTRCA-designated site in Monument Valley, Arizona. The following sections describe the actions the DOE and the Navajo Nation will take to encourage the participation of an informed public in this project.

9.2 PUBLIC PARTICIPATION

The National Environmental Policy Act (NEPA) of 1969 requires an evaluation of the environmental impacts of major Federal actions that may significantly affect the environment. Before remedial action construction can begin, an Environmental Assessment (EA) will be completed for the Monument Valley site. Public participation is an important part of the preparation of the EA; the participation requirements are detailed in the Council on Environmental Quality (CEQ) Regulations (effective July, 1979) for implementing the provisions of NEPA, and in the DOE guidelines of 1980 for NEPA compliance.

In preparing the EA, DOE has conducted and will continue to conduct individual meetings with community officials, interest groups, and private citizens to discuss the purpose of the proposed remedial action and ascertain the extent of public interest in this project. At these meetings, the public is given the opportunity to express their concerns and identify what they believe to be significant issues.

The identified issues are documented in the EA and incorporated into the decision-making process. The DOE accepts written comments for a 30-day period after publication of the EA. Interested parties will be given the opportunity to comment on the EA at an official comment-taking meeting after the EA is published.

In addition to meetings on the EA, the DOE will continue to hold public information meetings to describe the remedial action plan for the project and receive comments which may be used in the design for remedial action. These meetings will be advertised as to time and place.
Informal meetings and briefings have been and will continue to be held to provide information and project status updates and solicit public participation in the project activities. DOE, tribal and local officials, and interested citizens will be involved in frequent discussions regarding remedial action construction schedules, radiation monitoring reports, ground-water protection plans, and other project activities.

A task force made up of Oljato Chapter officials, community representatives, and local landowners was formed to advise DOE on matters pertaining to the remedial action planning effort. The DOE will work closely with this group in order to best implement community participation in the project, and ensure wide understanding of project goals and procedures.

9.3 PUBLIC INFORMATION

In order for public participation to be effective, the public must be informed concerning the remedial action project at Monument Valley. Several methods of information dissemination will be used by the DOE. Press releases, background statements, media briefings, or other necessary affirmative actions for information dissemination will be provided for the general public and appropriate officials at an early stage in the implementation of any new task or activity of interest.

The names and addresses of individuals, media representatives, and Federal, tribal, and local officials have been computerized for information dissemination purposes. Information is provided to interested persons in the Federal Government, tribal administration, and private citizens. A continuing effort will be made to update and expand the mailing list.

A public preconstruction meeting will be conducted by DOE. Principal topics of discussion will include the Remedial Action Plan and construction methods and schedules.

An on-site representative will be designated by DOE to respond to public inquiries during remedial action construction. This representative will provide information and meet frequently with the public throughout the construction period.

A variety of printed materials have been prepared concerning the UMTRA Project and the Monument Valley site. These include project fact sheets, a site fact sheet, and the Environmental Assessment (EA) document. As they are printed, these materials and other fact sheets and documents will be sent to interested individuals and are available in the public libraries, Chapter offices, and the Navajo Environmental Protection Administration. The same materials are also available at DOE-designated libraries nationwide.
BIBLIOGRAPHY


<table>
<thead>
<tr>
<th>Term</th>
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<tr>
<td>alluvium</td>
<td>Sediment deposited by a flowing stream.</td>
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<tr>
<td>alpha particle</td>
<td>A positively charged particle emitted from certain radionuclides. It is composed of two protons and two neutrons, and is identical to the helium nucleus.</td>
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<tr>
<td>ambient</td>
<td>Surrounding on all sides, encompassing.</td>
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<tr>
<td>animal unit month</td>
<td>The amount of feed or forage required by one mature cow and calf for one month.</td>
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<tr>
<td>anticline</td>
<td>A fold in rocks that is convex upward or had such an attitude at some stage of development.</td>
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<tr>
<td>aquifer</td>
<td>A formation containing sufficiently saturated permeable material to yield significant quantities of water to wells and springs.</td>
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<tr>
<td>aquitard</td>
<td>A water-bearing zone that allows transmission of water at a very slow rate, however, cannot yield significant quantities of water to production wells.</td>
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<tr>
<td>attenuate</td>
<td>To reduce the level of radiation emitted from a source.</td>
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<tr>
<td>background radiation</td>
<td>Radiation arising from radioactive material other than that under consideration. Background radiation due to cosmic rays and natural radioactivity is always present, and there is always background radiation due to the presence of radioactive substances in building materials, and the like.</td>
</tr>
<tr>
<td>bioassay</td>
<td>A method for quantitatively determining the concentration of radionuclides in a body by measuring the quantities of those radionuclides that are eliminated from the body, usually in the urine or the feces.</td>
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<tr>
<td>confined aquifer</td>
<td>An aquifer bounded above, and possibly below, by continuous beds or strata of much lower permeability. In general, a confined aquifer contains water under pressure that is significantly greater, or less than, the normal hydrostatic pressure gradient of water created by the force of gravity.</td>
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<tr>
<td>contamination</td>
<td>In this report, the presence of radioactive material in undesirable concentrations and in undesirable locations.</td>
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<tr>
<td>curie (Ci)</td>
<td>The unit of radioactivity of any nuclide, defined as precisely equal to $3.7 \times 10^{10}$ disintegrations per second.</td>
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DOE  U.S. Department of Energy.
daughter product(s)  A nuclide resulting from radioactive disintegration of a radionuclide, formed either directly or as a result of successive transformations in a radioactive series; it may be either radioactive or stable.
decay, radioactive  Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles, photons, or both.
decibels (dB)  A unit used to express power or intensity ratios in electrical or acoustical technology.
decontamination  The reduction of radioactive contamination from an area to a predetermined level set by a standards-setting body such as the EPA, by removing the contaminated material.
disposal  The planned, safe, permanent placement of radioactive waste.
dose  A general term denoting the quantity of radiation or energy absorbed, usually by a person; for special purposes, it must be qualified; if unqualified, it refers to absorbed dose.
dose, absorbed  The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material at the point of interest; given in units of rads.
dosimetry  The measurement of radiation doses.
eolian  Deposited after transport by wind.
exposure  The presence of gamma radiation that may deposit energy in an individual; given in units of roentgens.
external dose  The absorbed dose that is due to a radioactive source external to the individual as opposed to radiation emitted by inhaled or ingested sources.
floodplain  Lowland or relatively flat areas that are subject to flooding. A 100-year floodplain has a one percent or greater probability of flooding in any given year.
flux, radon  The emission of radon gas from the earth or other material, usually measured in units of picocuries per square meter per second.
fugitive dust  Dust particles which are dispersed from a construction site or from trucks during hauling.
gamma  A high energy and deep penetrating form of radiation.
<table>
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<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>gamma ray</td>
<td>High energy electromagnetic radiation emitted from some radiation radionuclides. The energy levels are specified for different radionuclides.</td>
</tr>
<tr>
<td>grazing capacity</td>
<td>The maximum number of livestock which can graze each year on a given area of range for a specific number of days without inducing a downward trend in forage production, forage quality, or soil.</td>
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<tr>
<td>ground water</td>
<td>Water below the land surface which occupies the voids within a geologic unit or formation.</td>
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<tr>
<td>half-life</td>
<td>The time required for 50 percent of the quantity of a radionuclide to decay into its daughters.</td>
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<tr>
<td>hydraulic gradient</td>
<td>The change in hydraulic head per unit of distance in a given direction. If not specified, the direction is generally understood to be in the maximum rate of decrease in hydraulic head.</td>
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<tr>
<td>immigrant</td>
<td>A person that moves into an area from outside the local area.</td>
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<tr>
<td>inert gas</td>
<td>One of the chemically unreactive gases: helium, neon, argon, krypton, xenon, and radon.</td>
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<tr>
<td>interbedded</td>
<td>Occurring between beds, or lying in a bed parallel to other beds of a different material.</td>
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<tr>
<td>licensing</td>
<td>In this report, the process by which the NRC will, after the remedial actions are completed, approve the final disposition and controls over a disposal site. It will include a finding that the site does not and will not constitute a danger to the public health and safety.</td>
</tr>
<tr>
<td>maintenance,</td>
<td>The repair of fencing, the repair or replacement of monitoring equipment, revegetation, minor additions to soil cover, and general upkeep of the stabilized tailings pile.</td>
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<tr>
<td>custodial</td>
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<tr>
<td>(passive)</td>
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<tr>
<td>micro</td>
<td>A prefix meaning one millionth (x 1/1,000,000 or 10⁻⁶).</td>
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<tr>
<td>milli</td>
<td>A prefix meaning one thousandth (x 1/1000 or 10⁻³).</td>
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<tr>
<td>Modified Mercalli</td>
<td>A standard scale for the evaluation of the local intensity of earthquakes based on observed phenomena such as the resulting level of damage. Not to be confused with magnitude, such as measured by the Richter scale, which is a measure of the comparative strength of earthquakes at their sources.</td>
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<tr>
<td>(scale)</td>
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<tr>
<td>monitor</td>
<td>To observe and make measurements to provide data for evaluating the performance and characteristics of the stabilized tailings pile.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>National Register of Historic Places</td>
<td>Established by the Historic Preservation Act of 1966. The Register is a listing of archaeological, historical, and architectural sites nominated for their local, state, or national significance by state and Federal agencies and approved by the Register staff.</td>
</tr>
<tr>
<td>permeability</td>
<td>A measure of the relative ease with which a porous medium can transmit liquid under a potential gradient. It is a property of the medium alone and independent of the liquid properties and the force field causing movement. Technically, the permeability of a medium is the volume of liquid of unit kinematic viscosity that will move in unit time under a unit potential gradient through a unit area at right angles to the direction of flow.</td>
</tr>
<tr>
<td>physiographic province</td>
<td>A region of similar structure and climate that has a common geomorphic history.</td>
</tr>
<tr>
<td>pico</td>
<td>A prefix meaning one trillionth ($1 \times 1/1,000,000,000,000$ or $10^{-12}$).</td>
</tr>
<tr>
<td>picocurie</td>
<td>A unit of radioactivity defined as 0.037 disintegrations per second.</td>
</tr>
<tr>
<td>piezometric surface</td>
<td>An imaginary surface that represents the static level of water (hydraulic head) in one specified aquifer.</td>
</tr>
<tr>
<td>radioactivity (radioactive decay)</td>
<td>The property of some nuclides of spontaneously emitting particles or gamma radiation or of spontaneous fission.</td>
</tr>
<tr>
<td>radioisotope</td>
<td>A radioactive isotope of an element with which it shares almost identical chemical properties.</td>
</tr>
<tr>
<td>radionuclide</td>
<td>A radioactive nuclide.</td>
</tr>
<tr>
<td>radium-226</td>
<td>A radioactive daughter product of uranium-238. Radium is present in all uranium-bearing ores; it has a half-life of 1620 years.</td>
</tr>
<tr>
<td>radon-daughter product</td>
<td>One of several short-lived radioactive daughter products of radon-222. All are solids.</td>
</tr>
<tr>
<td>recharge</td>
<td>The process by which water is absorbed by surficial soils or geologic units and is added to the zone of saturation.</td>
</tr>
<tr>
<td>Richter scale</td>
<td>A logarithmic scale ranging from one to 10 used to express the magnitude or total energy of an earthquake.</td>
</tr>
<tr>
<td>roentgen</td>
<td>A unit of measure of ionizing radiation in air; one roentgen in air is approximately equal to one rad and one rem in tissue.</td>
</tr>
</tbody>
</table>
Descriptive term for rock formed of sediment, especially: (1) clastic rocks (e.g., conglomerate, sandstone, shale) formed of fragments of other rock transported from their sources and deposited by water or wind, and (2) rocks formed by precipitation from solution (e.g., gypsum) or from secretions of organisms (e.g., limestone).

Pertaining to an earthquake or earth vibration.

Radiation health effects to the body of an individual, as opposed to genetic health effects to future generations.

The reduction of radioactive contamination in an area to a predetermined level by a standards-setting board such as the EPA, by encapsulating or covering the contaminated material.

The observation of the stabilized tailings pile for purposes of visual detection of need for custodial care, evidence of intrusion, and compliance with other license and regulatory requirements.

A fold in rocks in which the strata dip inward from both sides toward the axis.

The wastes remaining after most of the uranium has been extracted from uranium ore.

A radioactive daughter product of uranium-238; it has a half-life of 80,000 years and is the parent of radium-226.

A measure of the ability of an aquifer to transmit water. The value of transmissivity is equal to the product of the hydraulic conductivity and the thickness of the aquifer.


An aquifer that has a water table.

Toward a higher hydraulic gradient; the direction from which ground water flows.

A naturally occurring radioisotope with a half-life of 4.5 billion years; it is the parent of uranium-234, thorium-230, radium-226, radon-222, and others.
vicinity property: A property in the vicinity of the mill site that is determined by the DOE, in consultation with the NRC, to be contaminated with residual radioactive material derived from the site, and which is determined by the DOE to require remedial action.

water table: The surface in an unconfined ground-water body (i.e., unconfined aquifer) at which the pressure is equal to atmospheric pressure. This surface is defined by the level to which water will rise in a well penetrating the upper unconfined aquifer.

windblown: Off-pile tailings transported by wind erosion.
APPENDIX A

REGULATORY COMPLIANCE
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A.1 INTRODUCTION

This appendix identifies and describes the permits, licenses, and approvals required for the proposed action based upon the conceptual design (see Section 4.0 of the Remedial Action Plan). Other permits, licenses, and approvals may be required for activities beyond the scope of the Remedial Action Plan or due to modification of the conceptual design.

Procedures for preparing permit applications and agency review processes are outlined for each permit. The principal technical and supervisory personnel at the regulatory agencies are listed as well. The Remedial Action Contractor (RAC) should consider this appendix to be an introduction to the permitting process; additional details must be obtained from regulatory agencies. The Monument Valley site is within the jurisdictional boundary of different regional or district offices of Federal agencies. The appropriate office for consultation or permit applications is indicated for each permit.

Because the Monument Valley tailings site is within the Navajo Reservation, several special permitting conditions apply. Preliminary consultations with the Navajo Nation and the Bureau of Indian Affairs have been completed. This liaison should be maintained at each stage of the permitting process. Also, because of Navajo primacy in most natural resources and environmental affairs, most of the State of Arizona permits are not applicable to the project. In these cases, permitting authority reverts to Federal agencies (e.g., U.S. Environmental Protection Agency). For certain activities such as water wells and borrow sites, permits from the Navajo Nation are required in addition to the Federal or state permits.

A tentative schedule for regulatory compliance activity (Figure A.1.1) is included for initial planning purposes. Figure A.1.2, the compliance matrix, indicates the lead and cooperating agencies for each permit, license, or approval. The RAC should sequence the preparation and filing of permit applications so that approvals will be received in a timely manner without causing delay to construction activities. Environmental Services personnel of the Technical Assistance Contractor (TAC) will provide additional assistance as needed.
## Figure A.11
**Regulatory Compliance Schedule, Monument Valley Site**

<table>
<thead>
<tr>
<th>Permit/Approval - Prime Agency</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section 404 Dredge and Fill Permit - Corps of Engineers</strong></td>
<td>1-2</td>
</tr>
<tr>
<td><strong>National Pollutant Discharge Elimination System Permit - EPA</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Threatened or Endangered Species Consultation - USFWS</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Cultural Resource Clearance - SHPO</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sand and Gravel Permit - U.S. Bureau of Indian Affairs</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Revocable Use Permit - U.S. Bureau of Indian Affairs</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Right of Way Permit - U.S. Bureau of Indian Affairs</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Approval of Borrow Site Excavations - Navajo Tribe</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Water Purchase Contract/Water Use Permit - Navajo Tribe</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Water Well Drilling Permit - Navajo Tribe</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Approval of Well Sealing and Abandonment - Navajo Tribe</strong></td>
<td></td>
</tr>
</tbody>
</table>

**EPA - Environmental Protection Agency**

**SHPO - State Historic Preservation Officer**

**USFWS - U.S. Fish & Wildlife Service**

**Agency Consultation**

**Submit Application**

**Data Collection**

**Agency Review**

**Prepare Application or Report**

**Permit Approval**
### Figure A.1.1 (Cont.) Regulatory Compliance Schedule, Monument Valley Site

<table>
<thead>
<tr>
<th>Permit/Appearance - Prime Agency</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Highway Encroachment Permit - Utah Department of Transportation</td>
<td>1</td>
</tr>
<tr>
<td>Review of Transportation on State Highways - Utah Dept. of Transportation</td>
<td>2</td>
</tr>
<tr>
<td>County Road Encroachment Permit - San Juan County Roads Dept.</td>
<td>3</td>
</tr>
</tbody>
</table>

**Legend:**
- **□** Agency Consultation
- **△** Submit Application
- **○** Agency Review
- **□** Data Collection
- **□** Prepare Application or Report
- **□** Permit Approval

**Abbreviations:**
- EPA - Environmental Protection Agency
- SHPO - State Historic Preservation Officer
- USFWS - U.S. Fish & Wildlife Service
**FIGURE A.1.2**

**REGULATORY COMPLIANCE COORDINATION**

**MONUMENT VALLEY**

<table>
<thead>
<tr>
<th>PERMIT OR APPROVAL</th>
<th>CORPS OF ENGINEERS</th>
<th>U.S. EPA</th>
<th>U.S. F &amp; WS</th>
<th>ARIZONA SHPO</th>
<th>U.S. BIA</th>
<th>NAVAJO TRIBE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SECTION 404 DREDGE AND FILL PERMIT</td>
<td>L</td>
<td>C</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NPDES PERMIT</td>
<td>L</td>
<td>C</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THREATENED &amp; ENDANGERED SPECIES CONSULTATION</td>
<td>L</td>
<td>C</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>CONSIGNED WATER SERVICE CONTRACT</td>
<td>L</td>
<td>C</td>
<td></td>
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<td></td>
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<tr>
<td>CULTURAL RESOURCE CLEARANCE</td>
<td>L</td>
<td>C</td>
<td>C</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>SAND AND GRAVEL PERMIT</td>
<td>L</td>
<td>C</td>
<td></td>
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<tr>
<td>REVOCABLE USE PERMIT</td>
<td>L</td>
<td>C</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>RIGHT-OF-WAY PERMIT</td>
<td>L</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPROVAL OF BORROW SITE EXCAVATIONS</td>
<td>L</td>
<td></td>
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</tbody>
</table>

**L** - LEAD AGENCY  
**C** - COOPERATING OR CERTIFYING AGENCY
### Figure A.1.2 (Cont.)

**Regulatory Compliance Coordination**

**Monument Valley**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Water Purchase Contract/Water Use Permit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Well Drilling Permit</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approval of Well Sealing and Abandonment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporary Water Diversion Permit</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approval of Well Plugging</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Highway Encroachment Permit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review of Transportation of State Highways</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L = Lead Agency
ACTIVITY: SECTION 404 PERMIT FOR DISCHARGE OF DREDGED OR FILL MATERIAL


AGENCY/CONTACT: U.S. Army Corps of Engineers
Los Angeles District Office
Regulatory Branch, FPL-CO-R
P.O. Box 2711
Los Angeles, California 90053-2325
ATTN: Charles Holt
Chief, Regulatory Branch
Glen Lukos
Chief, South Coast Section
(213) 688-5606

PROCEDURE: The removal or placement of fill from, or into floodplains, or wetlands, as determined by the Corps of Engineers (COE), is subject to COE approval which is likely to be granted by the issuance of an individual Section 404 Permit.

A permit application consists of a completed "ENG Form 4345" which includes the following information:

1. Complete description of the proposed activity including vicinity maps and plan view and section drawings, sufficient for public notice.

2. Location and purpose of the proposed activity.

3. Schedule of the activity.

4. Names and addresses of adjoining property owners.

5. Location and dimensions of adjacent structures.

6. List of authorizations required by other Federal, interstate, state, or local agencies for the work, including all approvals received or denials already made.

Within 15 days of receipt of the application by the COE, the application is reviewed for completeness, and the applicant is notified of the need for additional information prior to further processing. A public notice of the application is issued by the COE, also within 15 days of receipt of the application. Comments from the public and from other government agencies (e.g., U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service) are considered by the COE in the impacts of the project and, in some cases, an Environmental Impact Statement (EIS). A public hearing may be scheduled in some circumstances. The COE determines whether or not a permit should be issued and prepares a statement of findings (SOF) or, in the case of an EIS, a record of decision (ROD).
SECTION 404 PERMIT (Concluded)

SPECIAL CONSIDERATIONS: The COE has determined that Cane Wash is considered to be a wetlands under the 404 permit program. A Section 404 permit will be required if this low-lying area would be affected by decontamination activities or related land contouring.

Consultation with the regional U.S. Environmental Protection Agency office, as required by Section 404C of the Clean Water Act, may be necessary in the permitting process.

SCHEDULE: Section 404 permits normally require 90 days for processing although simple applications may involve as little as 60 days.
ACTIVITY: NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT

LEGAL CITATION: Clean Water Act of 1977; 40 CFR 125

AGENCY/CONTACT: U.S. Environmental Protection Agency
Region IX
Permits Section
215 Fremont St.
San Francisco, California 94105
ATTN: Patricia Eklund
Chief of Permits Section
(415) 974-8283

PROCEDURE: This permit applies to all operations discharging to waters of the state from a point source. Application is made by filing completed U.S. Environmental Protection Agency (EPA) Forms 1 and 2C under the EPA Consolidated Permits Program. Information required on Form 1 includes:

1. Name, mailing address, and location of the facility.
2. Facility contact.
4. Existing Federal, state, or local permits.
5. Map covering an area extending at least one mile beyond the facility property boundaries. The map should be based on a 7.5-minute U.S. Geological Survey quadrangle map.
6. Description of the nature of the facility.

Form 2C requires the following information:

1. Location, by latitude and longitude, and number designation of each effluent outfall.
2. Name of receiving water for each outfall.
3. Schematic flow diagram indicating sources of water, operations contributing waste water for the effluent water balance, and treatment processes for each waste stream.
4. List of each operation, average flow, and treatment related to each outfall.
5. Description of the variation and frequency of water flow.
6. Explanation of any Federal, state, or local implementation schedule for construction or improvement of waste-water treatment or other environmental programs.
NPDES PERMIT (Continued)

(7) Influent and effluent characteristics:
   o Pollutants present.
   o Source of pollutants.
   o Concentration of pollutants.
   o Temperature of effluent.
   o Flow of effluent.
   o pH of effluent.
   o Total mass of pollutants discharged in a specified time interval.

SPECIAL CONSIDERATIONS: Although the state government of Arizona maintains EPA-approved NPDES programs, the State of Arizona will not assert primacy on Indian lands. The permit process should be initiated through the designated Regional Officer of the Federal EPA. The requirement for state permits involving non-Indian lands should not arise since the Remedial Action Plan specifies impoundments and drainage plans which will provide containment for the 25-year one-hour storm.

Form C may be used as an alternative to Form 2C in the application. The conceptual design specifies that a zero discharge retention pond will be used to receive contaminated water. For this type of facility, the main purpose in obtaining an NPDES permit is to limit the liability of the operator for discharges that may result from a very large precipitation event or other unanticipated situations. EPA officials encourage operators to obtain a permit for a no discharge facility. Prohibitions of a discharge permit include, but are not limited to, the following:

(1) No discharge is allowed that will violate state, regional, or local land use plans unless all requirements and conditions of applicable Federal and state statutes and regulations are met or will be met according to a schedule of compliance. Similarly, no discharge is permitted that by itself or in combination with other pollutants will result in pollution of the receiving waters in excess of standards, unless the permit contains effluent limitations and a schedule of compliance with water quality requirements.

(2) No discharge of any radiological, chemical, or biological warfare agent or high level radioactive waste is permitted. Limits of radiological wastes that may be discharged are determined by state water quality standards.

(3) No discharge from a point source that is in conflict with an established water quality management plan promulgated under Sections 201, 208, 209, and 303(e) of the Federal Water Pollution Control Act of 1972 and the Clean Water Act of 1977 is permitted unless the discharge permit contains limitations and a schedule of compliance approved by the EPA.

The frequency of measuring, monitoring, and reporting is dependent on specific discharges.
SCHEDULE: An applicant is to apply for a permit at least 180 days in advance of the date the discharge is to begin. In some cases, the EPA may determine that a site visit or extra information is necessary. In such a case, the applicant has 60 days to reply.
ACTIVITY: THREATENED OR ENDANGERED SPECIES CONSULTATION PROCESS


AGENCY/CONTACT: U.S. Fish and Wildlife Service
Ecological Services
2934 W. Fairmount Ave.
Phoenix, Arizona 85017
ATTN: Don Metz, Field Supervisor (602) 241-2493

Branch of Environmental Quality Services
Bureau of Indian Affairs
Navajo Area Office
P.O. Box M, Mail Code 305
Window Rock, Arizona 86515
ATTN: Jim Analla (602) 871-5151

PROCEDURE: A Federal agency must ensure that any action authorized, funded, or implemented by the agency is not likely to jeopardize the continued existence of any threatened or endangered (T&E) species or its critical habitat. The responsible Federal agency must consult with the U.S. Fish and Wildlife Service (USFWS) to determine what effect, if any, the proposed action might have on T&E species.

In most cases, a letter is sent by the Federal agency to the USFWS outlining the proposed action. If the USFWS determines that no T&E species would be adversely affected by the action, the USFWS responds stating their finding and that no further compliance measures are necessary. If the USFWS identifies that any T&E species may be affected, the Federal agency is required to prepare a biological assessment considering the species list selected by the USFWS.

SPECIAL CONSIDERATIONS: The USFWS indicated that two Federal candidate plant species (Astragalus crouquistir and Asclepias cutleri) and one plant species of special concern to the Navajo Tribe (Eremocrinum albomarginatum) may occur near the tailings site and proposed borrow sites. Field surveys will be conducted for these species near the tailings site in the spring of 1986. Similar surveys should be conducted at and near the borrow sites once their final location is determined.

SCHEDULE: After obtaining the list of T&E species from the USFWS, the Federal agency has 180 days or another mutually agreeable time period to complete a biological assessment. The Federal agency requests a Section 7 consultation, and the USFWS is required to issue a biological opinion within 90 days.
ACTIVITY: CULTURAL RESOURCE CLEARANCE

LEGAL CITATION: National Historic Preservation Act; 25 CFR 261 and 36 CFR 800

AGENCY/CONTACT: Arizona State Park Service
State Historical Preservation Office
1688 W. Adams Street
Phoenix, Arizona 85007
ATTN: Donna Schober
State Historical Preservation Officer
Sherry Lerner
Compliance Coordinator

Branch of Environmental Quality Services
Bureau of Indian Affairs
Navajo Area Office
P.O. Box M, Mail Code 305
Window Rock, Arizona 86515
ATTN: Jim Analla
Environmental Quality Services Officer
Mark Henderson, Archaeologist

Navajo Cultural Resources
Navajo Nation
P.O. Box 689
Window Rock, Arizona 86515
ATTN: Anthony Klessert
Program Manager
Ext. 1540

PROCEDURE: Prior to surface disturbing activities on Navajo Nation lands, cultural resource clearance must be obtained from the Bureau of Indian Affairs (BIA). The person or government agency proposing the activity must contract with an approved archaeologist to conduct a Class III archaeological survey of the land to be affected. Six copies of the survey report should be sent to the Branch of Environmental Quality Services, BIA. The BIA solicits the review and recommendations of the Navajo Nation. The BIA issues a letter of clearance in conjunction with the appropriate State Historic Preservation Officer (SHPO) stating stipulations for the proposed activity. Recommendations can range from no stipulations to avoidance or excavation and salvage of archaeological features that may have been identified.

During the review of the environmental assessment, the BIA, in conjunction with the appropriate SHPO, determines whether identified cultural resources are eligible for nomination to the National Register of Historic Places (NRHP). The DOE determines what effect the proposed action will have on eligible cultural resources. Comments on the determination of effect and the proposed mitigation measures are solicited from the BIA, SHPO, and the Advisory Council on Historic Preservation.
CULTURAL RESOURCE CLEARANCE (Concluded)

SPECIAL CONSIDERATIONS: A Class III archaeological survey has been completed at the Monument Valley site. The survey disclosed six sites eligible for nomination to the NRHP and two others which require further investigation. Final clearance is pending completion of data recovery from the sites noted in the Class III survey. At the present time, no cultural sites will be affected by the remedial action activities.

The Arizona SHPO has concurred with the survey conclusions. The review process will be expedited if reports are submitted simultaneously to the BIA and Arizona SHPOs.

The discovery of additional archaeological sites during the course of Federally assisted, permitted, funded, or licensed construction or land alteration must be reported to the BIA Archaeologist. If a previously undiscovered site is revealed during the course of construction, the official in charge should halt construction and request an on-site assessment by the BIA. The BIA will respond within 48 hours with a professional assessment of the significance of the site. In consultation with agency officials, the BIA Archaeologist makes an on-site decision for salvage, burial, or destruction of the site. The BIA Archaeologist will coordinate with the Interagency Archaeological Service of the U.S. Department of the Interior as required in 36 CFR 66.

SCHEDULE: Completion of a Class III archaeological survey usually requires two to four weeks, depending upon the size of the area and availability of archaeologists. Review by the BIA usually involves a minimum of eight weeks. In cases where identified archaeological resources may be eligible for nomination to the NRHP, an extended review period (up to six months) should be expected.
PROCEDURE: This permit is required for the excavation of borrow materials (earth, gravel, rock) within the Navajo Reservation. Issuance of a sand and gravel permit is based upon review of a completed application form 5-154j (original and four copies) and accompanying information. The following information is required:

(1) Name, address, and telephone number of applicant.

(2) Land ownership (either Navajo Nation or individual Navajo allottee's name).

(3) Location of proposed operation (map).

(4) Proposed expiration date of permit.

(5) Exact acreage of land to be covered by the permit.

(6) Metes and bounds description of the property boundary.

(7) Royalty rate or royalty waiver explanation.

(8) Description of the type of material to be mined.

(9) Performance bond to assure reclamation of the site (form 5-154b).

(10) Signatures of the majority of the Navajo Nation Tribal Council delegates for Tribal lands or written consent of current owners of allotted lands.

Exhibit A of the application should include:

(1) Description of the project.

(2) Description of project purpose and need.

(3) Summary of existing environmental conditions, including:
   o Land use.
   o Vegetation.
   o Water.
   o Air.
   o Biology.
   o Existing facilities.
(4) Statement of influence on the environment.

(5) Summary of environmental impacts.

(6) Mining and reclamation plan, including:
   - Type of equipment to be used.
   - Topsoil to be stockpiled for later reclamation use.
   - Revegetation procedures based on recommendations of the Branch of Land Operations, BIA.

The application is evaluated by the Realty Specialist to determine if a site-specific environmental assessment is needed in addition to the environmental assessment completed for the remedial action. Stipulations for impact mitigation may be attached to the permit approval.

SPECIAL CONSIDERATIONS: Concurrence must be obtained by the BIA from the local Navajo Chapter leadership and from the Navajo Nation Tribal Council prior to issuance of the permit. A production royalty is normally charged for the extraction of borrow materials; however, this requirement may be waived. Waiver of the royalty requirement also requires Navajo Nation Tribal Council approval. Cultural resource clearance for the borrow site must be obtained prior to permit approval.

SCHEDULE: The time required for review and processing of the application is typically three to six months although special handling of the application may considerably reduce the review period.
ACTIVITY: REVOCABLE USE PERMIT

LEGAL CITATION: 25 CFR 162

AGENCY/CONTACT: Bureau of Indian Affairs
Phoenix Area Office
P.O. Box 7007
Phoenix, Arizona 85011
ATTN: James Stevens
Area Director

Branch of Real Property Management
Bureau of Indian Affairs
Western Navajo Agency
P.O. Box 127
Tuba City, Arizona 86045
ATTN: Roy Dan, Agency Superintendent
Edmund Store, Realty Specialist

PROCEDURE: This permit is required for temporary activities such as test pit excavations and construction staging areas. To process the permit, the following are required.

(1) Name and address of applicant.

(2) Number of acres to be affected and legal location.

(3) Type of activity (e.g., test pit excavations).

(4) An environmental plan may be required.

(5) A bond may be required.

SPECIAL CONSIDERATIONS: The Revocable Use Permit is required for activities conducted outside the designated site boundaries and adjacent areas. Activities within the designated site boundaries and adjacent areas are authorized by the cooperative agreement between the DOE and the Navajo Nation. A cultural resource clearance and an environmental impact analysis may be required.

SCHEDULE: Permit review and approval will take four to eight weeks.
ACTIVITY: RIGHT-OF-WAY PERMIT

LEGAL CITATION: 25 CFR 169

AGENCY/CONTACT: Bureau of Indian Affairs
Navajo Area Office
P.O. Box M, Mail Code 305
Window Rock, Arizona 86515
ATTN: Wilson Barber, Jr., Area Director
Eva Cook, Realty Specialist
for Right-of-Way
(602) 871-5156

PROCEDURE: Right-of-Way Permits will be required for constructing or upgrading the access roads to the tailings and borrow sites. Application for a Right-of-Way Permit may be made either on the proper BIA form (no form number specified) or by formal letter, including the following information:

(1) Name and address of applicant.
(2) Purpose of intended right-of-way.
(3) Estimate of ton-miles and maximum loads.
(4) Attached map(s) showing roads to be used.
(5) Proposed duration of use.

Following a preliminary review, the BIA may require the applicant to submit an environmental assessment prepared according to the guidelines contained in 25 CFR 169.

SPECIAL CONSIDERATIONS: Issuance of a permit will be contingent upon the applicant's agreement to stipulations regarding load limits and road maintenance.

SCHEDULE: A Right-of-Way Permit is usually issued within 30 days following receipt of the application and, if required, environmental assessment. However, objections from affected Navajo Chapters could delay the process for several months.
ACTIVITY: APPROVAL OF BORROW SITE EXCAVATIONS

LEGAL CITATION: "General Surface Restoration Requirements for Sand and Gravel Operations," Navajo Environmental Protection Administration

AGENCY/CONTACT: Navajo Environmental Protection Administration
Navajo Nation
P.O. Box 308
Window Rock, Arizona 86515
ATTN: Louise A. Linkin
Executive Director

(602) 871-6585

PROCEDURE: The plans for borrow site excavations should be outlined in a letter that is sent to the Administration for approval. The plans should comply with the following specifications:

(1) Haul roads

- Existing haul roads shall be used whenever possible.
- Roads proposed for construction shall not exceed a grade of eight percent, except for pit ramps which should not exceed a 10 percent grade.
- Other design specifications should comply with Figure 6 of "General Surface Restoration Requirements for Sand and Gravel Operations," Navajo Environmental Protection Administration, June 26, 1980.
- Proposed roads should be no wider than is necessary for the safe operation of equipment.
- Roads that cross dry creeks or arroyos should provide adequate drainage either by ramping the road down to the base of the channel or by installing a suitable culvert if the channel will be filled.
- Roads should be designed with the consideration that most will be closed and rehabilitated following completion of the project. Rehabilitation should consist of replacement of stockpiled soil, scarifying of compacted surfaces, and construction of water bars. All disturbed areas should be revegetated if practical.

(2) Borrow pit closure and rehabilitation

- All excavations should be backfilled and recontoured to blend with the surrounding terrain. The site should be restored as nearly as practical to its original condition.
The disturbed site should be prepared to provide a seedbed for reestablishment of desirable vegetation and reshaped to blend with the natural contour. Such practices may include contouring, terracing, gouging, scarifying, mulching, fertilizing, seeding, and planting.

(3) Abandonment and rehabilitation reports

Upon completion of the required grading and backfilling, the permittee shall make a report to the Administration and request inspection for approval.

The permittee shall file reports with the Administration when planting is completed. Quarterly reports of rehabilitation activities are also required.

SPECIAL CONSIDERATIONS: Borrow material excavation requires (1) a lease from the Navajo Land Development Office, (2) approval from the Navajo Environmental Protection Administration, and (3) a Sand and Gravel Permit from the Bureau of Indian Affairs, Branch of Real Property Management. The consent of grazing allottees must be obtained prior to approval by the Administration.

SCHEDULE: Review by the Administration can require several weeks to several months depending upon the complexity of the operation.
ACTIVITY: WATER PURCHASE CONTRACT/WATER USE PERMIT

LEGAL CITATION: Navajo Tribal Water Code; Rules and Regulations of the Water Management Department

AGENCY/CONTACT: Water Management Department
Division of Water Resources
Navajo Nation
P.O. Box 308
Window Rock, Arizona 86515
ATTN: Masud Uz Zaman, Director (602) 729-5281

PROCEDURE: The Water Management Department issues water use permits on behalf of the Navajo Nation in the form of a "Standard Water Purchase Contract." A permit application is initiated by sending a letter and completed draft contract to the Department. The letter should contain the following information:

1. Description of the proposed use of the water.
2. Length of time water will be needed.
3. Schedule of anticipated rates of use for peak, low, and average demand.
4. Schedule of anticipated rates of overall amount of water required.
5. Proposed source of water.
6. Quality of water that is required.

The Water Management Department analyzes the availability of water, existing water quality, and alternative sources and determines whether it will grant tentative approval. Concurrences from other Tribal agencies are obtained, and the contract is forwarded to the Navajo Tribal Council Chairman for final approval.

The enforcement of water contracts is the responsibility of the Operations and Maintenance Department of the Division of Water Resources. A fee per unit volume is commonly required with each contract. Waiver or reduction of the water use fee may be possible upon negotiation with Navajo Nation leaders. This permit would apply to the use of existing wells at the Monument Valley site.

SPECIAL CONSIDERATIONS: None.

SCHEDULE: Approval of a water purchase contract usually requires four to eight weeks.
ACTIVITY: WATER WELL DRILLING PERMIT

LEGAL CITATION: Navajo Tribal Water Code; Rules and Regulations of the Water Management Department

AGENCY/CONTACT: Water Management Department
Division of Water Resources
Navajo Nation
P.O. Box 308
Window Rock, Arizona 86515
ATTN: Masud Uz Zaman, Director (602) 729-5281

PROCEDURE: This permit is required prior to the drilling and construction of water wells, including observation wells. Application is made by filing a completed water well permit application form with the Water Management Department. Information required in the application is as follows:

(1) Name, address, and telephone number of applicant.

(2) Type of permit and type of water use.

(3) Location: Navajo Chapter or district, state, county, township, range, and 1/4 1/4 1/4 section and UTM coordinates.

(4) Map indicating location of the well.

(5) Well description: proposed well depth, well diameter, casing diameter, production capacity, and drilling method.

(6) Driller's name, address, telephone number, and license number.

(7) Proposed starting and completion dates.

The application must be accompanied by a fee of $25 per well or per group of wells.

Staff members of the Water Management Department will review the application for completeness and circulate the permit application to the following officials for their concurrence:

(1) Grazing committee member/district land board member.

(2) Chapter Councilman.

(3) Director, Water Management Department.

Approval is granted by the Executive Director of the Division of Water Resources.

SPECIAL CONSIDERATIONS: The applicant is required to send copies of the following documents to the Water Management Department when they are available:

(1) Well completion reports.

A-22 MON Draft RAP
February, 1986
WATER WELL DRILLING PERMIT (Concluded)

(2) Well logs.

(3) Results of water sampling and chemical analysis.

Additional conditions of approval may be written into the permit.

SCHEDULE: Approval of well permits usually requires 30 to 60 days from the date of receipt by the Water Management Department. Additional time may be required if supplemental information is requested or the application is incomplete.
ACTIVITY: APPROVAL OF WELL SEALING AND ABANDONMENT

LEGAL CITATION: Navajo Tribal Water Code; Rules and Regulations of the Water Management Department

AGENCY/CONTACT: Water Management Department
Division of Water Resources
Navajo Nation
Window Rock, Arizona 86515
ATTN: Masud Uz Zaman, Director (602) 729-5281

PROCEDURE: Sealing of wells must comply with the Rules and Regulations of the Water Management Department. A report on the sealing of wells should be sent to the Department after the wells have been sealed.

SPECIAL CONSIDERATIONS: A variance from the rules may be requested for unusual situations where alternative well sealing procedures are warranted.

SCHEDULE: Well abandonment reports should be sent to the Water Management Department following completion of abandonment.
ACTIVITY: STATE HIGHWAY ENCROACHMENT PERMIT

LEGAL CITATION: Utah Code Annotated, Title 27-10-1 through 27-12-3

AGENCY/CONTACT: Utah Department of Transportation
2060 South 2400 West
Salt Lake City, Utah 84104
ATTN: Andy Sopko (801) 973-4588

PROCEDURE: A permit is required prior to performing any type of work on a state highway or highway right-of-way. The application must contain a description and the duration of the proposed activity and a map of the location. A field inspection by the Department will be conducted.

SPECIAL CONSIDERATIONS: None.

SCHEDULE: Normal timeframe is one week.
ACTIVITY: REVIEW OF TRANSPORTATION ON STATE HIGHWAYS

LEGAL CITATION: Utah Code Annotated, Title 54-6, Federal Motor Carrier Code

AGENCY/CONTACT: Utah Department of Transportation
4501 South 2400 West
Salt Lake City, Utah 84119
ATTN: Legrand Jones
(801) 965-4272

PROCEDURE: The Department of Transportation will be responsible for reviewing and approving use of state highway transportation corridors to and from the project sites. Information to be reviewed includes the routing of trucks, frequency and time of delivery, expected load capacities, and procedures for transportation of tailings.

SPECIAL CONSIDERATIONS: None.

SCHEDULE: The review must be completed prior to construction.
CONCLUDING REMARKS

The preceding list of permits is considered to be comprehensive. No other issues or permit requirements have been identified which are considered relevant to the current Remedial Action Plan for the Monument Valley tailings site.

The activity discussed does not require specific permits at this time but requires regulatory compliance or additional permits - if the Remedial Action Plan is modified significantly.

SPILL PREVENTION CONTROL AND COUNTERMEASURES PLAN (SPCC)

If on-site fuel and oil storage facilities exceed 1320 gallons, or any single on-site fuel or oil tank exceeds 660 gallons capacity, the EPA requires the operator to prepare an SPCC plan meeting the specifications cited in 40 CFR 112 and certified by a professional engineer. No permit is required, but a copy of the plan must be kept at the fuel storage site and be available for review by the EPA in the event of a spill or general inspection.
APPENDIX B

ENGINEERING DESIGN
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B.1 PILE CONFIGURATION

B.1.1 OVERVIEW

This appendix provides details of the engineering design and summaries of calculations that were made in preparing the design.

The stabilized Monument Valley tailings pile will cover approximately 18.5 acres. Access to the pile is from the existing Road 6440 east of the Monument Valley Navajo Tribal Park. Areas around the pile will be recontoured to direct runoff water around and away from the pile (Figure B.1.1).

B.1.2 DECONTAMINATION AND RESTORATION

After removing contaminated materials, the mill area and part of the tailings area will be recontoured for positive drainage. The restored site, excluding the final pile, will be released for unrestricted use.

B.1.3 EMBANKMENT CONSTRUCTION

The Monument Valley pile will contain approximately 950,000 cubic yards of tailings and contaminated materials (Table B.1.1) and will be designed to provide long-term stability and to control radon gas emanation.

Table B.1.1 Volumes of tailings and contaminated materials

<table>
<thead>
<tr>
<th>Description</th>
<th>Volume (cy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New pile and pond area</td>
<td>702,160</td>
</tr>
<tr>
<td>Heap leach pads</td>
<td>197,070</td>
</tr>
<tr>
<td>Ore storage and mill yard</td>
<td>13,690</td>
</tr>
<tr>
<td>Batch leach yard</td>
<td>27,930</td>
</tr>
<tr>
<td>Old pile remnant</td>
<td>3,200</td>
</tr>
<tr>
<td>Rubble piles</td>
<td>300</td>
</tr>
<tr>
<td>Roads</td>
<td>2,400</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>946,750</strong></td>
</tr>
</tbody>
</table>

Stabilization in place is proposed at the site of the new pile. The first step in the pile construction is the stabilization of the foundation soils. The top of the new pile must be removed in order to perform dynamic compaction of the foundation soils because the optimal effective depth of this compaction technique is about 50 feet. These tailings will be relocated to the west side of the new pile leaving a maximum depth of tailings of, at most, 25 feet. Dynamic compaction of
the new pile foundation soils, extending out 100 feet from the perimeter of the stabilized pile area, can then proceed. Because of the dynamic compaction, differential and total settlement will not affect the integrity or longevity of the pile.

The old pile tailings and the other contaminated materials (approximately 400,000 cy) will then be placed on the new tailings forming the pile as shown in Figure B.1.1. The sideslopes will not be steeper than five horizontal to one vertical. A typical cross-section is shown in Figure B.1.2.

Limiting the pile sideslopes to 20 percent grade will provide the necessary factor of safety against slope failure and reduces the potential for erosion (see Section B.3, Slope Stability, and Section B.8, Erosion Protection - Apron and Pile).

Organic materials, such as grubbed vegetation, will first be burned and the ash evenly distributed throughout the pile. Burning will be done in accordance with regulations as established by the Navajo Nation.

B.1.4 COVER CONSTRUCTION

The tailings radon exhalation rate will be reduced to EPA standards by placing a cover over the consolidated tailings and contaminated materials. The cover or radon barrier will be constructed of compacted sandy clay soil at or above optimum moisture content to reduce the diffusion of radon gasses. Approximately one foot of cover material will be required (see Figure B.1.2 and Section B.5, Radon Barrier).

The radon barrier will be protected by a six-inch-thick sand bedding layer, a six-inch-thick rock filter layer, and one-foot-thick layer of erosion resistant rock. The filter layers will protect the fine-grained soils of the radon barrier from piping and erosion.

The rock layers are designed to withstand the erosive effects due to the occurrence of the Probable Maximum Precipitation (PMP) on the pile. For the Monument Valley area, the local one-hour PMP storm is 7.9 inches (NOAA, 1977). Based on this PMP, the maximum 2.5-minute intensity was calculated, considering a time of concentration of 2.5 minutes. This 2.5-minute intensity was converted to an equivalent one-hour rainfall intensity of 52.14 inches per hour, which was then used for sizing of erosion barrier material. Required rock size for armoring the pile and summaries of the calculations are presented in Section B.8, Erosion Protection - Apron and Pile.

The rock layer will also protect the embankment from wind erosion and will discourage plant root intrusion and burrowing animals.
FIGURE B.1.2
TYPICAL CROSS-SECTION, MONUMENT VALLEY SITE
B.1.5 CROSS-SECTIONS

Figure B.1.2 shows the typical cross-section of the proposed pile with an exaggerated vertical scale. Figure B.1.2 also shows the actual 1:1 scale cross-section of the pile.
B.2 SUBGRADE

B.2.1 DESIGN REQUIREMENTS

Subgrade materials at the Monument Valley site were evaluated to determine if existing subgrade conditions were suitable for stabilization in place. This investigation concluded that some subgrade modifications are necessary to implement the conceptual design.

B.2.2 MATERIAL PROPERTIES

The near-surface soils generally consist of loose to medium-dense, unconsolidated, fine-grained dune sand to silty sand with isolated zones of fine-grained silty clay. 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. Detailed material properties, individual boring logs, and stratigraphic sections of subgrade materials underlying the tailings pile are presented in Appendix D, Site Characterization.

B.2.3 EXCAVATION CRITERIA

Excavation of the old tailings pile and the other contaminated areas will be required as part of the remedial action. The excavation and construction sequence at the site should be conducted in a manner that prevents the ponding of water during the construction phase. In addition, the lines and grades of the excavation should have a maximum slope of three horizontal to one vertical.

B.2.4 MATERIAL QUANTITIES

The total volume of materials to be excavated is summarized in Table B.2.1.

The volume of material to be excavated at the existing tailings site is based on the depth of tailings and extent of the contaminated materials at the processing site.

B.2.5 LIQUEFACTION AND CYCLIC MOBILITY

Liquefaction and/or cyclic mobility can occur only in saturated cohesionless soils (sands and silts) due to cyclic loading caused by earthquake-induced ground motions (Seed, 1976). Liquefaction occurs when the effective stress is reduced to zero by earthquake-induced pore water pressure buildup. When this occurs the soil loses shear strength, becomes essentially a viscous fluid, and fails. Cyclic
Table B.2.1 Excavation volumes (in place)

<table>
<thead>
<tr>
<th>Subarea/description</th>
<th>Area (acres)</th>
<th>Depth (ft)</th>
<th>Volume (cy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of new pile</td>
<td>6.1</td>
<td>10.2</td>
<td>100,000</td>
</tr>
<tr>
<td>Pond area east of pile</td>
<td>9.7</td>
<td>3.6</td>
<td>56,620</td>
</tr>
<tr>
<td>Heap leach area</td>
<td>10.6</td>
<td>12.0</td>
<td>205,090</td>
</tr>
<tr>
<td>Area E (ore storage)</td>
<td>23.9</td>
<td>scattered</td>
<td>17,110</td>
</tr>
<tr>
<td>Area C (batch leach)</td>
<td>7.5</td>
<td>2.3</td>
<td>27,930</td>
</tr>
<tr>
<td>Area D (old pile remnant)</td>
<td>1.0</td>
<td>2.5</td>
<td>4,000</td>
</tr>
<tr>
<td>Rubble piles</td>
<td>0.2</td>
<td>1.0</td>
<td>300</td>
</tr>
<tr>
<td>Roads</td>
<td>1.5</td>
<td>1.2</td>
<td>3,000</td>
</tr>
<tr>
<td>Total</td>
<td>60.5</td>
<td></td>
<td>414,050</td>
</tr>
</tbody>
</table>

mobility, on the other hand, occurs in denser soils. The pore pressure buildup causes loss of shear strength but results in a limited amount of shear strain (generally not greater than 15 percent) before pore pressures are reduced and shear strength is regained.

There are several factors that are important in assessing the potential for liquefaction or cyclic mobility or both. Of these the most important are: (1) the ratio of earthquake-induced shear stresses in the soil to the vertical effective stress; (2) the relative density \( D_r \) of the soil; (3) the types of soil present; and (4) the presence of saturated soils.

There is a practical maximum acceleration and a maximum shear stress that can be produced by the design earthquake. As soil depth increases, the ratio of maximum possible shear stress to effective stress becomes smaller. This generally precludes liquefaction and/or cyclic mobility at depths greater than approximately 50 feet below the ground surface.

Most researchers agree that there is a relative density beyond which liquefaction cannot occur. Liquefaction can readily occur in soils with a relative density \( D_r \) of less than 40 percent (Seed, 1976). Generally, beyond a \( D_r = 70 \) percent neither liquefaction nor cyclic mobility can occur (Casagrande, 1975).

The liquefaction potential of the tailings pile's foundation was analyzed using the simplified method as outlined by Seed and Idriss (1982). This method uses empirical data relating the SPT blowcounts of a deposit as determined in the field, to the limiting cyclic shear strength of the deposit for the given earthquake Richter magnitude (M). This limiting cyclic shear strength of the soil is then compared to the estimated shear stress developed by the earthquake or,
where

\[ \frac{T}{\sigma_y'} = 0.65 \frac{a_{\text{max}}}{g} \frac{\sigma_y}{\sigma_y'} r_d \]

\( a_{\text{max}} \) = maximum horizontal acceleration as a fraction of the acceleration of gravity.

\( g \) = acceleration of gravity (32.2 ft/sec²).

\( \sigma_y \) = total vertical stress at the center of the layer in question.

\( \sigma_y' \) = effective vertical stress at center of layer depth.

\( r_d \) = depth reduction factor, as determined from charts in referenced paper by Seed and Idriss (1982).

Thus a factor of safety for the soil layer can be estimated. Seed and Idriss (1982) recommend a factor of safety ranging between 1.2 and 1.5, depending on the consequence of failure.

The profile that was analyzed for liquefaction was derived from boring 603. Although this boring is approximately 400 feet to the east of the new pile, this boring is both the closest hole to the pile and a good representation of the subsurface stratigraphy and ground-water level for the pile vicinity. Boring 603 does, however, encounter sands which are slightly more dense than the value used for the liquefaction analysis, which was the lower bound of one standard deviation \((S_x)\) from the mean \((\bar{x})\) of all the SPT blowcounts around the pile (i.e., \(S_x - \bar{x}\) = lower bound).

The profile of boring 603 was then projected back to the edge of the pile to incorporate any changes in surface elevation in the area which would affect the depth to ground water, and subsequently the effective confining pressures. The data in the vicinity of the new pile suggest the water levels are shallow along established washes, and relatively deep away from the washes. Boring 603, which has water eight feet from the surface, is approximately 200 feet southeast of a small wash. The southern end of the new pile is approximately 100 feet northwest of this same wash. The elevation of boring 603 is 13 feet less than the toe of the pile. Therefore, if the ground water is at the same elevation at equal distances from each side of the wash, the depth to water could be approximately 15 feet, or possibly less, at the edge of the pile. The ground-water characteristics on the north side of the pile, which are not governed by nearby washes, suggest depths of 25 feet or more, based on calculated gradients from the nearby wells.

The profile which was analyzed for liquefaction potential included 55 feet of loose (four blows/foot, or relative density = 46 percent), unconsolidated fine-grained dune sand and silty sand with a water level at 15 feet. These density parameters are discussed in more detail in Appendix D, Site Characterization. A sensitivity analysis performed on
the profile indicates a relative density of 57 percent (11 blows/foot) would have to be achieved to bring the factor of safety up to 1.5 against liquefaction in the foundation sand around the perimeter of the new pile.

The final design should consider field and laboratory testing, and computer modeling to confirm assumptions made in this section. If the foundation sands still appear susceptible to liquefaction after a detailed site characterization, the remedial action may include densification of the foundation material by mechanical methods, such as deep dynamic compaction.

Under current and expected future conditions, the tailings themselves will not be saturated, and therefore not susceptible to liquefaction.

B.2.6 FOUNDATION STABILIZATION

Part of the foundation of the new pile area will be stabilized against the possibility of liquefaction using deep dynamic compaction. The area to be compacted is approximately 28 acres and includes the stabilized pile area and a 100-foot-wide zone around the perimeter of the pile except where bedrock is exposed at the surface. Dynamic compaction is achieved by dropping a weight, typically up to 30 tons, from a height of 100 feet or more. These compaction parameters will be determined following a more detailed site characterization. Three passes are generally made over the entire area to be compacted. That portion of the pile that rests on bedrock will not require dynamic compaction of the foundation material.
B.3 SLOPE STABILITY

B.3.1 INTRODUCTION

The tailings embankment was analyzed for stability under both static and dynamic loadings for the period immediately following construction as well as for the long term.

Slope stability analysis, in all of the commonly used forms, involves the comparison of the strength mobilized by the soil to the forces acting to move the soil mass downslope. The ratio of these forces is called the factor of safety (FS) and can be estimated for any arbitrarily selected potential failure surface within a soil slope. It is obvious that when the forces acting to destabilize the soil above a given surface exceed the soil strength mobilized along that surface, a failure can be expected to occur. In other words, when the FS < 1.0, indicating that the limit of the strength of the soil has been exceeded, the slope fails.

The primary forces which act to destabilize a given slope are:

- Soil weight.
- Hydraulic forces.
- Earthquake accelerations.

A component of the weight of the soil above a potential failure surface will act to move the soil mass downslope parallel to that surface.

The presence of water within a slope will tend to produce downslope forces due to the hydraulic forces developed in tension cracks which often form at the crest of the slope. Also, more importantly, the water pressures along the potential failure surface tend to reduce the contact (normal) forces along this surface and thus reduce the maximum frictional shear forces which can be mobilized within the soil.

The accelerations developed in an earthquake can have two effects: (1) they produce a horizontal force which is assumed to act at the center of gravity of the soil mass, and (2) they cause alternating positive and negative shear strains within the soil mass and thus can cause a reduction in the shear strength of certain soils and/or generate increased pore pressures which, if great enough, can cause liquefaction (see Section B.2.5).

The horizontal force produced by earthquake accelerations causes two deleterious effects: a component of these forces will act downslope along the potential failure plane and thus tend to destabilize the slope while, at the same time, another component of these forces tends to act in an upward direction perpendicular to the potential
failure plane. This causes a reduction in the normal force on the plane and thus reduces the shear strength of the soil in much the same manner as does water pressure.

B.3.2 METHOD OF ANALYSIS

In order to estimate the minimum factor of safety of the tailings pile, an infinite slope limit equilibrium analysis was used. The infinite slope analysis is based on the assumption that the potential failure surface will be approximately planar and that this surface will be approximately parallel to the ground surface at a depth which is small compared to the height of the slope. Infinite slope failure is considered to be the critical scenario since for C=0 slopes the chart solutions for circular failure reduce to the same equation as was used for the infinite slope analysis. Figure B.3.1 shows the location of Section C-C', which was the section analyzed for slope stability. Section C-C' was chosen for analysis because it is in the zone which exhibits the highest water table and the steepest embankment slope. This section was modeled as a deep, homogeneous sand profile to bedrock. This section was used for both static and dynamic conditions.

On large slopes composed of cohesionless soils it has been found that the infinite slope analysis gives the lowest factor of safety and is thus very conservative (Duncan and Buchignani, 1975). If a soil slope actually does exhibit cohesion it will merely cause the factor of safety to be larger than that predicted by the infinite slope analysis with zero cohesion.

Under static conditions the equation

\[ FS = \frac{\tan \phi}{\tan i} \]

(1)

can be used to estimate the factor of safety (FS) of the slope (Duncan and Buchignani, 1975). In this equation \( \phi \) is the effective friction angle of the soil and \( i \) is the angle of the slope to the horizontal.

For the case of a soil slope in which cohesion is thought to have an important influence, as in the case of undrained loading in a saturated or partially saturated clay soil, the following equation can be used (Duncan and Buchignani, 1975):

\[ FS = \frac{\tan \phi}{\tan i} + B \frac{C}{\gamma H} \]

where:  
\( C = \) Cohesion (psf).  
\( \gamma = \) unit weight of soil (pcf).  
\( H = \) thickness of the soil layer (feet).  
\( B = \) slope geometry factor.

Under dynamic conditions, the following equation can be used to calculate the factor of safety for the infinite slope analysis (Huang, 1983):
FIGURE B.3.1
LOCATION OF SECTION SLOPE STABILITY ANALYSIS, MONUMENT VALLEY
\[
FS = \frac{[(1-r_u) \cos i - k \sin i] \tan \phi'}{\sin i + k \cos i}
\]

where

- \(r_u\) = pore pressure (psf).
- \(k\) = seismic coefficient (0.66 \(a_{\text{max}}\)).

Similar safety factors were calculated using the following equation (Hadj-Hamon and Kavazanjian, 1985):

\[
FS = \frac{[1-m \gamma_w/\gamma) z \gamma \cos^2 i - \Delta r_u] \tan \phi}{\gamma z \cos 1 \sin 1 + k \gamma z \cos 1}
\]

where:

- \(m\) = height of water table above assumed failure surface.
- \(\gamma_w\) = unit weight of water (62.4 pcf).
- \(z\) = depth to failure surface (feet).

This equation can be reduced to the following equation for a cohesionless, dry slope where the earthquake-induced change in pore pressure (\(\Delta r_u\)) equals zero and the height of the water table above the assumed failure surface (\(m\)) also equals zero:

\[
FS = \frac{\cos 1 \tan \phi}{\sin 1 + k}
\]

The Maximum Credible Earthquake (MCE) is estimated to be a Richter magnitude 6.2 at a distance of 15 km (see seismicity in Section D.3, Appendix D, Site Characterization). Using the attenuation relationships developed by Campbell (1981), the MCE would produce an \(a_{\text{max}}\) of about 0.21g at the site (Section D.3).

Research has found that as the motion is transmitted from the bedrock up through the soil deposit at a site, the energy waves may be altered. The exact nature of this alteration depends on the physical properties of the soil and depth to bedrock. Seed and Idriss (1982) have developed curves relating the effects of this alteration to acceleration for various types of soil deposits. Subgrade conditions at Monument Valley can be characterized as a "deep cohesionless deposit," ranging from approximately 50 to 70 feet deep. The effect of deposits of this depth at the predicted bedrock acceleration indicate an attenuation of the bedrock acceleration from 0.21g to 0.17g at the surface.

Two-thirds of the surface acceleration of 0.17g was used as the seismic coefficient (\(k\)) in the pseudo-static analysis for the seismic long-term stability of the embankment slope (0.17g \(x\) 0.66 = 0.11g). This reduction has been agreed upon by the DOE and the NRC to reflect the value deemed most appropriate to provide a mean value for input into the stability analysis.
The seismic coefficient used for the short-term (end of construction) dynamic analysis was taken as the lesser of 0.10 or the acceleration with a 90 percent probability of not being exceeded in 50 years as quoted by Algermissen et al. (1982) (DOE, 1985). The value given by Algermissen is <0.04 and thus \( k = 0.10 \) was used in the analysis of slope stability for short-term dynamic loading.

### B.3.3 RESULTS OF SLOPE STABILITY ANALYSES

The results of the slope stability analyses are summarized in Table B.3.1.

**Table B.3.1 Results of slope stability analysis**

<table>
<thead>
<tr>
<th>Conditiona</th>
<th>Friction angle (degrees)</th>
<th>Cohesion (psf)</th>
<th>Factor of safety Static</th>
<th>Dynamicb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-term</td>
<td>0</td>
<td>1900</td>
<td>77 (1.3)</td>
<td>NP</td>
</tr>
<tr>
<td>Long-term</td>
<td>0</td>
<td>1900</td>
<td>77 (1.5)</td>
<td>NP</td>
</tr>
<tr>
<td>Sand tailings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-term</td>
<td>34.9</td>
<td>0</td>
<td>3.43 (1.3)</td>
<td>2.18c(1.0)</td>
</tr>
<tr>
<td>Long-term</td>
<td>34.9</td>
<td>0</td>
<td>3.43 (1.5)</td>
<td>2.18c(1.0)</td>
</tr>
</tbody>
</table>

aAll slopes are assumed to be composed of single homogeneous soil.
bThe equation used to calculate the dynamic factor for safety can be expected to be in error by 14 percent, or more, for slope angles \( \geq 10^\circ \) (about 5:1).
c\( CK = 2/3 \ a_{max} \) or 0.11g.
NP - not performed.
(1.3) - indicates the accepted minimum factor of safety is 1.3 (DOE, 1985).

### B.3.3.1 Short-term stability

During remedial action work, the stability of the pile is gradually reduced until it reaches a minimum immediately following completion of construction work. In general, the reason for this is that the loading due to placement of cover, buttresses, and the like, is assumed to be so rapid that there would be no time for induced excess pore water pressure to dissipate or for consolidation to occur in fine-grained material. Once consolidation begins, the void ratio and the water content would begin to decrease and the strength of the tailings decreases. If the material is free draining, such as
sand, the pore pressures would dissipate rapidly; this is known as a drained condition and the material is modeled with drained strengths. This would also be the case in an unsaturated condition. Both conditions are valid for the Monument Valley pile.

Since drained strength parameters were used for the tailings and foundation sands in the short-term analysis of Section C-C', the analyses will be identical to those discussed in Section B.3.3.2, Long-Term Stability.

The short-term infinite slope analysis was performed for the one-foot thick radon barrier cover. The resulting safety factor was 77.0 when a cohesion of 1900 psf was used. No dynamic analysis was performed since the safety factor is far in exceedance of the minimum required.

The dynamic analysis discussed in Section B.3.3.2, Long-Term Stability, will also apply to the short-term dynamic analysis since the soil parameters are the same, and the seismic coefficient is only 0.01g less than the long-term coefficient.

### B.3.3.2 Long-term stability

Once construction work is complete, any pore pressures that have developed will decrease until they have totally dissipated. The soils are consolidated and at equilibrium with the existing stress system. In this case, the strengths of the materials are not influenced by pore pressures but are impacted mainly by the particle-to-particle stresses and the characteristics of the individual particles. The strengths that best model this type of behavior are the effective stresses as measured in the triaxial "R" test, or drained conditions.

The strength parameters used to model the long-term stability behavior of the tailings sands are discussed in Appendix D, Site Characterization. The minimum factor of safety for this case is 3.4 for the infinite slope analysis through the sand tailings. This analysis is above the required minimum of 1.5 (Sowers, 1979; DOE, 1985).

The long-term static safety factor for the radon barrier material in the infinite slope scenario was estimated to be nearly the same as that calculated for the short-term analysis since the strength parameters (i.e., C = 1900 psf, \( \phi = 0 \)) were derived from laboratory tests of material at approximately the same moisture content as that projected for long-term moisture (18 percent).
The seismic stability analysis was performed on the same section using the infinite slope model with the same strength parameters and a pseudo-static seismic coefficient of 0.11g. The factor of safety for this condition is 2.18, which is above the 1.0 minimum required factor of safety for this condition (DOE, 1985).
The limits of contamination across the Mexican Hat site are estimated in Appendix D, Site Characterization. Not all contaminated material on the site will need to be excavated for the stabilization in place concept. The contaminated soils and tailings along the far northeastern end of the upper pile, in the lower tailings pile, and beneath the lower pile will not be excavated.

It is also the case that in some areas excavation will likely remove more material than is estimated to be contaminated. This is expected to be true in some parts of the ore storage/mill yard and the windblown area. For these two reasons, then, the volumes of excavated material to be placed in the final embankment will differ from the volumes of contaminated material identified in Appendix D. Table B.4.1 presents a summary of the extent, depth, volume, and average radium-226 content of contaminated soil to be excavated for placement in the final embankment. In the following paragraphs the assumptions leading to these values are described. In Section 6.4.4 the average radium-226 profile in the final embankment is developed, along with the profile of radon transport properties in the final pile configuration.

Table B.4.1 Summary of excavated materials

<table>
<thead>
<tr>
<th>Subarea/description</th>
<th>Area (acres)</th>
<th>Depth (ft)</th>
<th>Volume (cy)</th>
<th>Ra-226 (pCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of new pile</td>
<td>6.1</td>
<td>10.2</td>
<td>100,000</td>
<td>65</td>
</tr>
<tr>
<td>Pond area east of pile</td>
<td>9.7</td>
<td>3.6</td>
<td>56,090</td>
<td>174</td>
</tr>
<tr>
<td>Heap leach area</td>
<td>10.6</td>
<td>12.0</td>
<td>205,620</td>
<td>52</td>
</tr>
<tr>
<td>Area E (ore storage)</td>
<td>23.9</td>
<td>scattered</td>
<td>17,110</td>
<td>51</td>
</tr>
<tr>
<td>Area C (batch leach)</td>
<td>7.5</td>
<td>2.3</td>
<td>27,930</td>
<td>40</td>
</tr>
<tr>
<td>Area D (old pile remnant)</td>
<td>1.0</td>
<td>2.5</td>
<td>4,000</td>
<td>36</td>
</tr>
<tr>
<td>Rubble piles</td>
<td>0.2</td>
<td>1.0</td>
<td>300</td>
<td>25</td>
</tr>
<tr>
<td>Roads</td>
<td>1.5</td>
<td>1.2</td>
<td>3,000</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>60.5</td>
<td></td>
<td>414,050</td>
<td></td>
</tr>
</tbody>
</table>

The general construction sequence for placing the contaminated materials in their final configuration calls for movement of 100,000 cy from the top of the existing new pile. This material would be placed immediately adjacent to the western side of the new pile. The contamination in the pond area on the eastern side of the new pile would then be excavated from an area of about 9.7 acres. Next the heap leach pad material would be evenly placed over the resulting mound. Finally, all other contamination (Areas C, D, and E and the rubble piles and roads) would be placed over the former material. All distinct layers will be placed over the entire surface of the previous layer. In all areas of excavation, it is assumed that no backfill will be applied.
B.4.1 NEW PILE

The top of the new pile representing about 6.1 acres will be moved to the western side of the pile resulting in the basic footprint shown in Figure B.1.1. The average Ra-226 concentration of the new pile material is developed in Appendix D, Site Characterization. It is assumed that this concentration exists throughout the new pile material in its final configuration.

B.4.2 POND AREA

The contaminated material in the pond area east of the new pile which will be excavated extends over about 9.7 acres to an average depth of 3.1 feet (48,270 cy). The depths of contamination above the 5 pCi/g limit range from less than 0.5 foot to 11 feet. Due to the varying depth to the excavation surface, it is likely that unavoidable overexcavation will occur. It is estimated that an additional 0.5 foot below the 5 pCi/g limit will be removed along with the contaminated material. This is assumed to occur over the entire 9.7-acre area which is shown in Figure B.4.1.

The additional 0.5 foot contributes another 7820 cy to the volume, but reduces the average Ra-226 concentration. The average concentration of the contaminated material (15 sampling holes) is 202 pCi/g for the 48,270 cy. Mixing this with an additional 7820 cy of natural alluvium due to overexcavation results in a Ra-226 concentration of 174 pCi/g for the 56,090 cy to be removed.

B.4.3 HEAP LEACH AREA

After placing the material excavated from the pond area, the heap leach pad area will be added. The Ra-226 concentration of the heap leach pad material is developed in Appendix D, Site Characterization (54 pCi/g). This material sits in an arroyo bounded by Shinarump outcroppings on either side over sandy alluvium. With an area of 10.6 acres and an average depth to the 5 pCi/g limit of 11.5 feet, the heap leach pads contain 197,070 cy.

Although the excavation surface is relatively flat beneath the pads, access to the material is constrained to one direction (from the mouth of the arroyo). For this reason, it is reasonable to expect some mixing of the material at the interface during excavation. It is assumed that 0.5 foot of unavoidable overexcavation will occur. This will contribute an additional 8550 cy to the volume and will lower the average Ra-226 concentration to about 52 pCi/g.
FIGURE B.4.1
EXTENT OF CONTAMINATION TO BE REMOVED FROM THE POND AREA EAST OF THE NEW PILE
B.4.4 OTHER CONTAMINATED AREAS

All of the other areas of contamination listed in Table B.4.1 will be combined into a single layer placed over that of the heap leach pad material. The average properties of this layer are volume weighted averages of the properties of the various materials of which it is composed. These are discussed in the following paragraphs.

The contamination in the former mill yard and ore storage area (Area E) is determined to be 13,690 cy in Appendix D. This material is scattered across an area of about 23.9 acres with the vast majority in one of three settings. About half the volume is contained in large ore storage piles and loadout ramps constructed of pit run rock from the nearby mine. About half of the remaining material consists of gravel material also brought from the mine and used as fill for leveling on the exposed Shinarump Formation. The final quarter of the material is remnant tailings from the old pile (upgrading process), and is located along the eastern edge of Area E, spilling over the edge of the arroyo containing the heap leach pads. All of the contamination in Area E is in contact with the exposed Shinarump Formation and effectively fills the cracks characteristic of that sandstone.

Excavation of the material in Area E may be difficult due to the amount of material which must be removed from the cracks. Thus, it is assumed that approximately 25 percent unavoidable overexcavation of this material will occur. The Ra-226 concentration of the Area E material is 64 pCi/g (see Appendix D, Site Characterization). With a 25 percent increase in volume, the Ra-226 concentration of the 17,110 cy becomes 51 pCi/g.

The contaminated material atop the Shinarump Formation between the heap leach pad and the existing new pile is denoted as Area C. This area was the site of the batch leach facility which processed the old pile material into the new pile material. It extends across 7.5 acres and primarily consists of two types of material. The first of these is composed of pit run rock from the mine for leveling fill and loadout ramp construction. The second type of material consists of the remnants of the old pile spilled during the batch leach process. Although the final stabilized pile configuration extends over the eastern half of Area C, the depth of contamination in the area to be covered is small (about 0.5 foot). Thus, the volume of contamination estimated in Appendix D is approximately the same volume as will be excavated. This is due to the fact that about 0.5 foot of unavoidable excavation of material below the contamination in the western half of Area C balances the 0.5 foot of contamination which will be covered by the final configuration over the eastern half of Area C. The Ra-226 concentration in Area C is determined to be 45 pCi/g in Appendix D. With an additional 0.5 foot of unavoidable overexcavation in the western half of Area C, the estimated Ra-226 concentration of the excavated material is 40 pCi/g.

The old pile remnant along the south side of the heap leach pad designated as Area D will also result in unavoidable overexcavation. A value of 25 percent is estimated. This results in a total volume of
4000 cy at a Ra-226 concentration of 36 pCi/g. The rubble piles to the north and south of the site are assumed to be excavated cleanly with no overexcavation.

The contaminated roads around the site are assumed to result in 25 percent unavoidable overexcavation. This results in a volume of 3000 cy with an average Ra-226 concentration of 40 pCi/g.

The total material from Areas C, D, and E and the rubble piles and roads is 52,340 cy. The volume weighted average Ra-226 concentration is 43 pCi/g.

B.4.5 EMBANKMENT RADIUM-226 PROFILE

The radium-226 distribution in the proposed tailings embankment is based on the radioactivity of the off-pile and off-site excavated soils (as calculated in the preceding Sections B.4.1 through B.4.4), the radioactivity of the unexcavated soils lying within the boundaries of the embankment, and the radium distribution in the recontoured tailings pile.

Based on the volumes of the materials, the thickness of each of the four layers is presented in Table B.4.2. Each layer is assumed to be placed evenly over the one below.

In addition to the Ra-226 concentration difference, each layer also has an independent set of physical properties which affect radon transport. These properties include diffusion coefficient, emanating fraction, porosity, bulk density, and moisture content. Each of these parameters for the four layers is discussed in the following paragraphs and presented in Table B.4.2.

Diffusion coefficients and moisture content

Diffusion coefficient measurements of the material from the new pile, pond area, and the heap leach pads have been made as a function of moisture content at the density to which the final pile will be compacted (90 percent of the maximum dry density). These measurements are discussed in Appendix D, Site Characterization. The long-term moisture content of the materials has been estimated. For the material from the new pile (deepest layer) which is extremely coarse-grained sand, the long-term moisture is estimated as two percent. The long-term moisture content of the pond area material, the heap leach pad material, and all other contaminated material is estimated as five percent. The diffusion coefficients for these layers at the estimated long-term moisture content are presented in Table B.4.2.
<table>
<thead>
<tr>
<th>Layer material description</th>
<th>Volume (cy)</th>
<th>Thickness (feet)</th>
<th>Average Ra-226 concentration (pCi/g)</th>
<th>Long-term moisture (%)</th>
<th>Diffusion coefficient (cm²/s)</th>
<th>Emanating fraction</th>
<th>Porosity (g/cm³)</th>
<th>Bulk density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas C, D, and E and rubble and roads</td>
<td>52,340</td>
<td>1.8</td>
<td>43</td>
<td>5</td>
<td>0.0286</td>
<td>0.29</td>
<td>0.36</td>
<td>1.77</td>
</tr>
<tr>
<td>Heap leach pads</td>
<td>205,620</td>
<td>7.1</td>
<td>52</td>
<td>5</td>
<td>0.0286</td>
<td>0.29</td>
<td>0.36</td>
<td>1.77</td>
</tr>
<tr>
<td>Pond area</td>
<td>56,090</td>
<td>3.9</td>
<td>174</td>
<td>5</td>
<td>0.0285</td>
<td>0.29</td>
<td>0.56</td>
<td>1.26</td>
</tr>
<tr>
<td>New pile</td>
<td>653,890</td>
<td>45.9</td>
<td>65</td>
<td>2</td>
<td>0.048</td>
<td>0.23</td>
<td>0.43</td>
<td>1.54</td>
</tr>
</tbody>
</table>
Emanating fraction

Samples analyzed for emanating fraction were collected from only the new pile and heap leach pad material. These averaged 0.26 and 0.29, respectively. The emanating fraction for the other layers is assumed to be 0.29, more related to the heap leach pad material.

Porosity and bulk density

Porosity and bulk density measurements were made of the same sample analyzed for the diffusion coefficient, and are reported in Appendix D, Site Characterization.
B.5 RADON BARRIER

B.5.1 SUMMARY

Based on the assumptions and calculations summarized in the following paragraphs, it is found that a radon barrier cover of one-foot thickness is required to reduce the flux of radon to the applicable EPA limit of .20 pCi/m²s. The radon flux through this cover is expected to average less than 15 pCi/m²s above background. The calculations are based on information presented in Appendix D, Site Characterization, and the preceding Section 8.4 of this appendix.

B.5.2 ASSUMPTIONS

The stabilization in place option for the Monument Valley site requires placing off-pile materials on the recontoured tailings piles. The following assumptions affected the radon barrier design:

- It will be possible to place contaminated soils excavated from the pond area and heap leach pads as two layers on the recontoured tailings, and to place contaminated soils from Areas C, D, and E and rubble and road areas as an outer layer.

- Heap leach pad average values of the radon emanating fraction are suitable for describing material from the pond area and Areas C, D, and E and rubble and roads.

- Values of the radon diffusion coefficient determined from the heap leach pad samples are suitable for describing contaminated soils from Areas C, D, and E and rubble and roads.

- It will not be necessary to move the base of the existing new tailings pile or any sub-pile contaminated soil since this area will be covered by the stabilized embankment.

- The available cover materials are adequately represented by the borrow samples obtained for geotechnical and diffusion coefficient analyses.

- The average moisture contents for the stabilized pile and cover, as predicted by engineering analyses, are suitable estimates of the long-term average condition of the pile.

- The compaction and placement of the tailings, other contaminated materials, and cover soils are sufficient to inhibit settlement and cracking of the cover.

B.5.3 METHOD

The thickness of cover material required to limit radon flux to 20 pCi/m²s is calculated using the computer code RAECOM (NRC, 1984). The mathematical model implemented in RAECOM describes one-dimensional...
steady-state radon diffusion through a two-phase multilayer system of porous media, representing the tailings pile and its cover.

Multiple layers of tailings and cover are allowed, with differences in physical, radiological, and diffusional properties represented by seven layer-specific input parameters. Radon concentrations in both soil-air and soil-water phases are treated, as well as the exchange between phases. Boundary conditions are the radon flux into the bottom of the pile and the air concentration of radon at the surface of the pile. In addition, interface conditions are applied, requiring continuity of both flux and concentration in both phases at layer interface. The exact simultaneous solution to the coupled radon mass balance and flux equations for the two phases is performed using matrix algebra for the general n-layer case.

The seven values required for each layer of the tailings pile system modeled by RAECOM are:

- Thickness of layer (cm).
- Bulk density (g/cm³).
- Porosity (fractional).
- Moisture content (percent, dry weight basis).
- Emanating fraction of radon (fractional).
- Radon diffusion coefficient (cm²/s).
- Radium concentration (pCi/g).

In addition to these parameters describing the layers of the stabilized pile, RAECOM requires input of the total number of layers in the pile and the layer to be optimized in meeting the specific flux limit (20 pCi/m²s) at the surface. Also the radon boundary conditions at the top and bottom of the pile must be specified. The bottom condition is set to zero pCi/m²s for tailings piles. The top condition is the observed ambient radon concentration (pCi/l) in air near the site. The selected values for each parameter listed above are presented in Table 6.4.2 for the tailings materials.

The UMTRA Project radon barrier design philosophy is based on the guidance given by the Environmental Protection Agency in the background information on their remedial action standards (EPA, 1983a,b). In these it is required that reasonable assurance be provided that the long-term annual average radon release rate be less than 20 pCi/m²s from the surface of the stabilized pile. This standard is a design standard, not a performance standard, and is to be met through the use of the best available technology and information at the time of the stabilization design. In designing to the EPA flux limit it is necessary to use pile averaged values for parameters such as radon diffusion coefficients or the emanating fraction of radon. Likewise, time-averaged values of other parameters, such as tailings and cover moisture contents, are appropriate.

It is recognized that under real conditions there will be areas on a stabilized pile which exceed the radon flux limit, but also areas below the limit; there will be times when environmental conditions
result in pile average fluxes that exceed the limit, but other times when different environmental conditions result in fluxes far below the standard. It is the intent of the UMTRA Project radon barrier design to acknowledge these variations and to provide a cover that will limit the average release rates to less than 20 pCi/m²s. It should be clear that worst case or highly conservative assumptions and parameter values are not used.

Of the parameter values presented in Table B.4.2 and described below, all are considered to be the best estimate of the mean value with one exception: the long-term moisture contents are conservative estimates of the moisture content of the tailings and cover materials. It is difficult to obtain reasonable measurements of the average long-term moisture content, thus an estimate of the driest likely long-term average value is used as a conservative value for this parameter. Other parameters, such as radon diffusion coefficients which vary as a function of moisture content, have values that are the best estimate of the mean value at the conservative moisture content.

B.5.4 COVER PHYSICAL PROPERTIES

The proposed structure of the embankment has six components: (1) the recontoured new tailings pile and unexcavated peripheral contamination along the eastern half of Area C (batch leach area); (2) a layer of contaminated material from the pond area; (3) a layer comprised of material from the heap leach pads; (4) a layer made up of all other contamination on the site; (5) the radon barrier cover; and (6) a rock and gravel erosion protection layer. The erosion protection layer is ignored for radon barrier design.

The proposed material for the radon barrier is from the Comb Ridge borrow site. This material is the only suitable cover material in the vicinity of the Monument Valley site. Samples from three test pits (TP-40, TP-41, and TP-42) were analyzed for their radon transport properties. Table B.5.1 lists the diffusion coefficients of these three samples as a function of moisture content at the density to which the cover will be compacted (95 percent of maximum dry density).

Moisture content

The long-term moisture content of the cover material has been estimated at 18 percent. The long-term moisture content of the radon barrier material, contaminated materials, and tailings material is determined based upon the following:

- Data on the in-situ moisture content.
- Optimum moisture content as determined by ATSM D698.
- The moisture content at which the material will be placed.
- Capillary-moisture relationship data from -0.1 to -15 bars of suction.
Table B.5.1 Radon diffusion coefficients for cover soils

<table>
<thead>
<tr>
<th>Sample</th>
<th>Max. dry density (g/cc)</th>
<th>Specific gravity</th>
<th>Optimum moisture (% dry wt.)</th>
<th>As tested dry density (g/cc)</th>
<th>Test moisture (% dry wt.)</th>
<th>Diffusion coefficient (sq cm/s)</th>
<th>Porosity (fraction)</th>
<th>Saturation (fraction)</th>
</tr>
</thead>
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<tr>
<td>MONO1-TP41 6-12'</td>
<td>1.610</td>
<td>2.74</td>
<td>22.1</td>
<td>1.53</td>
<td>5.2</td>
<td>2.20E-02</td>
<td>0.44</td>
<td>0.18</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.52</td>
<td>5.8</td>
<td>1.50E-02</td>
<td>0.45</td>
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<td></td>
<td>1.54</td>
<td>10.1</td>
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<td></td>
<td>1.54</td>
<td>10.7</td>
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<td></td>
<td></td>
<td>1.54</td>
<td>16.0</td>
<td>1.90E-02</td>
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<td></td>
<td>1.54</td>
<td>16.7</td>
<td>1.70E-02</td>
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<td></td>
<td>1.54</td>
<td>22.3</td>
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<td>1.53</td>
<td>22.0</td>
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<td>0.77</td>
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<td>MONO1-TP40 5-6'</td>
<td>1.730</td>
<td>2.72</td>
<td>18.8</td>
<td>1.63</td>
<td>6.5</td>
<td>3.40E-02</td>
<td>0.40</td>
<td>0.27</td>
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<td></td>
<td></td>
<td>1.64</td>
<td>5.1</td>
<td>2.50E-02</td>
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<td>1.66</td>
<td>8.4</td>
<td>1.40E-02</td>
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<td>1.65</td>
<td>9.2</td>
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<td>1.66</td>
<td>12.0</td>
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<td>1.64</td>
<td>19.6</td>
<td>3.40E-03</td>
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<tr>
<td>MONO1-TP42 0-6'</td>
<td>1.730</td>
<td>2.77</td>
<td>19.4</td>
<td>1.65</td>
<td>4.6</td>
<td>1.90E-02</td>
<td>0.41</td>
<td>0.19</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>1.64</td>
<td>5.5</td>
<td>2.30E-02</td>
<td>0.41</td>
<td>0.22</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.65</td>
<td>9.1</td>
<td>2.60E-02</td>
<td>0.40</td>
<td>0.37</td>
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<td>1.66</td>
<td>8.0</td>
<td>1.90E-02</td>
<td>0.40</td>
<td>0.37</td>
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<td></td>
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<td></td>
<td>1.65</td>
<td>14.3</td>
<td>2.10E-02</td>
<td>0.40</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.65</td>
<td>19.7</td>
<td>1.10E-03</td>
<td>0.41</td>
<td>0.80</td>
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<td></td>
<td></td>
<td></td>
<td>1.65</td>
<td>18.6</td>
<td>3.60E-04</td>
<td>0.40</td>
<td>0.76</td>
</tr>
</tbody>
</table>
Tailings (new pile)

The average optimum moisture content of the new tailings is 15.5 percent. The tailings will be reshaped, moisture conditioned, and compacted during remedial action at a moisture content zero to five percent below optimum. Two samples were tested of -1 bar of suction and the -1 bar and -15 bar moisture content were predicted by Rawls et al. (1982). The results of this analysis showed a measured -1 bar moisture content of 1.64 percent, a predicted -1 bar of 3.4 percent, and a -15 bar of 2.1 percent based on soil gradation properties. Recognizing that the tailings will be covered with a lower permeability material and that it will be moisture conditioned, a long-term moisture content of two percent was chosen as a conservative value.

Tailings (old pile)

The average optimum moisture content of the old tailings is 9.6 percent. The tailings will be picked up, moisture conditioned, and compacted over the new tailings during remedial action at a moisture content of five percent below optimum. One sample was tested at -1 bar of suction and the -1 bar and -15 bar suction were predicted by Gupta and Larson (1979). The results of this analysis showed a measured -1 bar moisture content of 7.3 percent, a predicted -1 bar of 5.2 percent, and a -15 bar of 4.8 percent based on soil gradation properties. Recognizing that the tailings will be covered with a lower permeability material and that the tailings will be moisture conditioned, a long-term moisture content of five percent was chosen as a conservative value.

Radon barrier

The average optimum moisture content of the Comb Ridge borrow material is 20.1 percent. The borrow material will be moisture conditioned and compacted during remedial action at a moisture content of zero to three percent above optimum. Three samples were tested for these capillary-moisture relationships from -0.3 to -15 bars of suction. The results of these tests showed a range for the -15 bar suction of 14.0 to 21.1 percent with an average of 17.6 percent. Based on these results a conservative long-term moisture content of 18 percent was chosen.

Bulk density

The bulk densities of tailings and cover given in Tables B.4.2 and B.5.1 were based on standard Proctor tests and reflect the design compaction of 90 percent of the maximum dry density for tailings and contaminated soil and 95 percent for cover.
Porosity

The tailings and cover porosities given in Tables B.4.2 and B.5.1 are calculated from the bulk densities at the design compaction using the specific gravity of the material. The equation used is

Porosity = 1 - (bulk density/specific gravity).

Radon diffusion coefficients

Radon diffusion coefficients have been measured for tailings, contaminated soils, and cover soils from around the Monument Valley site. The available data are presented in Appendix D, Site Characterization, and Table B.5.1. They are plotted against moisture saturation in Figures B.5.1 through B.5.4. Plotted with the data are two curves. One is the general correlation presented in NUREG/CR-3533 (NRC, 1984), the other is the best fit of that functional form to the specific set of values for each material. The iterative least squares best fit method used is described by Smith et al., 1986. The best fit curve is used to interpolate diffusion coefficient values for particular materials.

Table B.5.2 summarizes the diffusion coefficients for each of the several materials, at their estimated long-term moisture content. Note that the diffusion coefficient measurements for contaminated material from the heap leach pads are used to estimate the coefficients for materials from Areas C, D, and E and rubble and roads.

B.5.5 COVER THICKNESS

Only a single cover configuration was considered in the design of the stabilized embankment. This is due to the poor diffusion coefficient and long-term moisture content retention properties of the vast majority of available materials. The cover material from the Comb Ridge borrow site is near the site and exists in quantities sufficient for the cover required.

Based on the properties of the stabilized layers summarized in Tables B.4.2 and B.5.2, the required thickness of the cover to bring the average flux from the cover surface down to 20 pCi/m²/s is 0.7 foot (21 cm). This is conservatively rounded up to the nearest half foot to a proposed thickness of one foot. This is somewhat smaller than typical covers required for other sites in the UMTRA Project. Contributing to the requirement for such a thin cover is the fact that the contaminated material is relatively low in Ra-226 content. In addition, the cover material is estimated to have a relatively high long-term moisture content (18 percent). At a thickness of one foot, the proposed cover actually reduces the flux to less than 15 pCi/g.
FIGURE B.5.1
RADON DIFFUSION COEFFICIENT vs.
MOISTURE FOR MATERIAL FROM THE NEW PILE
Evaporation Pond

--- = NUREG/CR-3533 Correlation
--- = LSOFIT Correlation
= TP-7 Evaporation Pond

Diffusion Coefficient (cm^2/s)

Moisture Saturation Fraction

**FIGURE B.5.2**
RADON DIFFUSION COEFFICIENT vs.
MOISTURE FOR MATERIAL FROM THE EVAPORATION POND AREA
FIGURE B.5.3
RADON DIFFUSION COEFFICIENT vs. MOISTURE FOR MATERIAL FROM THE HEAP LEACH PAD
FIGURE B.5.4
RADON DIFFUSION COEFFICIENT vs.
MOISTURE FOR MATERIAL FROM THE COMB RIDGE BORROW SITE
Table 8.5.2 Summary of the diffusion coefficients for all layers of the proposed final pile

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>Thickness (feet)</th>
<th>Compaction(^a) (percent)</th>
<th>Long-term moisture (percent dry weight)</th>
<th>Dry density (g/cm(^3))</th>
<th>Porosity (fraction)</th>
<th>Moisture saturation (fraction)</th>
<th>Diffusion coefficient (cm(^2)/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New pile</td>
<td>45.9</td>
<td>90</td>
<td>2</td>
<td>1.54</td>
<td>0.425</td>
<td>0.072</td>
<td>0.048</td>
</tr>
<tr>
<td>2</td>
<td>Pond area</td>
<td>3.9</td>
<td>90</td>
<td>5</td>
<td>1.26</td>
<td>0.558</td>
<td>0.113</td>
<td>0.0285</td>
</tr>
<tr>
<td>3</td>
<td>Heap leach pads</td>
<td>7.1</td>
<td>90</td>
<td>5</td>
<td>1.77</td>
<td>0.36</td>
<td>0.246</td>
<td>0.0286</td>
</tr>
<tr>
<td>4</td>
<td>Areas C, D, and E and rubble and roads</td>
<td>1.8</td>
<td>90</td>
<td>5</td>
<td>1.77</td>
<td>0.36</td>
<td>0.246</td>
<td>0.0286</td>
</tr>
<tr>
<td>5</td>
<td>Cover (Comb Ridge)</td>
<td>--</td>
<td>95</td>
<td>18</td>
<td>1.62</td>
<td>0.413</td>
<td>0.707</td>
<td>0.00393</td>
</tr>
</tbody>
</table>

\(^a\)Percent of maximum dry density.
The cover design for the pile is intended to give a long-term annual average flux of 20 pCi/m²s. However, some conservative assumptions are implicit which indicate the actual flux should, in fact, be less.

The design moisture content of the pile is intended to be the driest long-term moisture content maintained by the pile materials considering climate, the consistency and compaction of the material, and the depth of the material in the pile. To the degree the actual moisture content remains above the design moisture content, the actual flux will be less than the design flux.

Any periods of harsh winter will add an additional degree of safety not reflected in the design. Whenever the soil is very wet, frozen, or covered with snow, the radon is effectively blocked from escaping into the atmosphere. Depending on the period over which such conditions exist, there will be a reduction in the actual annual average flux as compared to the design flux.

In the design of the pile, no radon flux attenuation was attributed to the rock and gravel cover that is to be applied to the pile as erosion protection. There is some decrease in the radon flux due to this cover, thus a safety factor is present. Since the erosion protection is designed to withstand extreme erosive events, it is likely that its contribution to radon flux reduction will persist for an extensive period of time.

No safety factors are intentionally applied in the design of the radon barrier, which is in agreement with the design nature of the radon flux standard as expressed by the EPA in its comments on the basis of the regulations. It is the intent of this discussion, however, to make clear that there are reasons to expect that the annual average flux measured around a stabilized pile would be lower than the design flux.

8.5.6 SENSITIVITY ANALYSIS

A sensitivity analysis evaluating the effect of error in the parameter values used for estimating the cover thickness was done for the most influential parameter, cover moisture content.

The moisture content, 18 percent, used for the Comb Ridge borrow material is a very conservative estimate of the long-term average moisture that can be maintained by this material. Actual measurements of the -15 bar moisture content of the three samples of this material were 14.0, 17.6, and 21.1 percent (average = 17.6 percent). A better estimate of the average long-term moisture content is the -5 bar moisture. Actual measurements of the -5 bar moisture content of the three Comb Ridge samples were 17.1, 20.0, and 24.5 percent (average = 20.5 percent). If 20.5 percent is accepted as the mean long-term moisture content, then 18 percent (the value used in the cover design) is comparable to the lowest moisture which will likely ever be achieved.
by this material. The sensitivity analysis must compare the cover thickness difference between 20.5 percent and 18 percent to obtain an estimate of the amount of conservatism represented by the conservative long-term estimate that has been used (18 percent).

The moisture saturation at 20.5 percent moisture content of the cover material is 0.804 and the best fit equation for the diffusion coefficient vs. moisture data indicates a mean diffusion coefficient at this saturation is 0.000874 cm²/s. The required cover thickness at this value is considerably less than the one foot specified.

8.5.7 DESIGN INSTRUCTIONS

The conceptual radon barrier design presented in the previous sections is based on the best available information. During construction, the RAC could encounter circumstances which might significantly affect the design. Should the radon barrier require modification, the following paragraphs describe the qualitative criteria which should be used in the design.

Layering the contaminated materials with the least contaminated at the top and increasing with depth will minimize the cover thickness. If significant quantities of additional contamination are discovered during construction, then the source terms, volumes, and layer sequence in the conceptual design may have to be modified. The reasoning and justification for the conceptual radon barrier design have been presented in enough detail that the RAC may follow the same steps in the event that modification is required.

The final cover placed by the RAC will be sampled much more completely than was performed for the conceptual design, which is based on only three preliminary samples from the Comb Ridge borrow area. Although the Comb Ridge borrow area is the only nearby site identified, other sources of cover material may be found. Regardless of the specific source finally chosen, it will be sampled and diffusion coefficient measurements performed before cover material is placed. In addition, "as placed" diffusion coefficient measurements will be made while the cover is being constructed.

It is suggested that a minimum of 40 diffusion coefficient measurements be performed. The first 20 to 25 of these should be of the borrow material as soon as the final source is chosen. Of these bulk samples, about half should be used to determine the overall dependence of the cover material's radon diffusion coefficient upon moisture. These determinations should be made across the entire moisture saturation range from 0.1 to 0.9.

The remaining half of the bulk samples should be used to determine the diffusion coefficient at moistures in a relatively narrow range around the predicted long-term moisture content. Using the Comb Ridge material, the predicted long-term moisture content is about 18 percent (71 percent moisture saturation fraction). Diffusion coefficient
measurements on the second half of the samples from the borrow area should be made at moistures ranging from about 10 percent to 25 percent. This will allow an evaluation of the standard error (uncertainty) of the mean value at any predicted long-term moisture content in a reasonable range.

The second 20 to 25 samples should be collected "as placed" during the cover construction. Thus they will be near optimum moisture content for that material and higher than the predicted long-term moisture content. Radon diffusion coefficients should be measured over the same range (10 to 25 percent) around the predicted long-term moisture content.

The results of the diffusion coefficient measurements from the borrow area will be used to design the actual thickness of the cover to be constructed. The results of the final sampling of the cover as placed will serve as confirming evidence that the flux standard will be met. No additional cover will be placed, even if the final diffusion coefficient measurements result in a predicted flux in excess of the standard.
B.6 GROUND SETTLEMENT

When the stress on a given soil layer is increased due to the placement of a new load, the soil layer tends to compress according to the mechanisms of elastic response or consolidation or both. Elastic response occurs in all soils and occurs immediately upon placement of the load. Consolidation generally occurs immediately in coarse-grained or unsaturated soils. When the load is first applied to fine-grained saturated, or nearly saturated soils, the pore water, which is essentially incompressible, takes the load. It takes time, depending on the soil hydraulic conductivity and the degree of saturation, for the pore pressures generated by the load to dissipate. As this pressure dissipates, the load is transferred to the soil particles and settlement occurs. Soils that consolidate upon loading are termed visco-elastic since they include a time factor in their stress-strain response. Consolidation settlement is thus time-dependent and may not be "immediate." In addition, all soils tend to consolidate or "creep" in the long term. This condition is called secondary consolidation.

Due to their granular, free draining properties, settlement in the Monument Valley foundation sand and tailings is expected to be immediate even though portions of the foundation are saturated. Total settlement and differential settlement across the site was modeled along Section D-D'. This section is shown in Figure 8.5.5. This instantaneous settlement in the coarse-grained soils was estimated using the following equation (Duncan and Buchignani, 1975):

\[ \rho_1 = \frac{5\sigma}{(N-1.5)C_B} \]

where

- \( \rho_1 \) = immediate settlement (in).
- \( \sigma \) = bearing pressure (tsf).
- \( N \) = minimum SPT blow count.
- \( C_B \) = width correction factor from charts in reference.

The calculated immediate settlement, after deep dynamic compaction of the foundation sand to 57 percent relative density, is 0.067. The immediate settlement calculated within the compacted tailings pile is 1.8 inches.

The secondary settlement from the elastic compression of the sands was calculated for one year, 10 years, and 30 years. Based on the results discussed in this section, it can be estimated that the slope of the line defining secondary settlement with time flattens out quickly. The total strain developed in the cover after 30 years is well below the threshold for cover cracking as discussed in this section. Therefore it is estimated that any additional settlement occurring after 30 years would not significantly impact the differential or total settlement analyses.

Secondary settlement is calculated by the equation (Schmertman, 1978; Duncan and Buchignani, 1976):
\[ \rho_t = \rho_i + C_t \]

where

- \( \rho_t \): secondary settlement (inches).
- \( \rho_i \): initial elastic settlement (inches).
- \( C_t \): time rate factor from charts in reference.

Based on the immediate settlement previously calculated, the expected secondary settlement of the tailings and foundation sand is 3.2 inches for one year, 3.8 inches for 10 years, and 4.1 inches for 30 years.

The anticipated buildup of tensile strain in the cover material was calculated based on the existing tailings and foundation sand remaining in the present loose condition (relative density of 46 percent). This would represent the worst case since it can be anticipated that densification of this material will be required on the existing pile and foundation to reduce the liquefaction potential. The maximum strain buildup in the radon barrier is expected to be 0.02 percent. A strain of 0.10 percent is considered to be a conservative threshold required for clay cover cracking to develop (Leonards and Narain, 1963).

Therefore only minor differential settlement-induced tensile strain is expected in the cover and thus will not endanger its structural integrity, induce cracking, or reduce its radon attenuation characteristics. Nor will it cause preferential pathways for storm-water runoff and gully formation.
8.7 SITE DRAINAGE

B.7.1 REGIONAL OVERVIEW

Cane Valley Wash is the nearest major watercourse to the Monument Valley site. The main ephemeral stream channel is approximately 1500 feet east of the designated site. A western segment of the wash is located between the main channel and new tailings pile. The flood analysis using the HEC-1 model shows that PMF flows in Cane Valley Wash would be approximately 80,000 cubic feet per second (COE, 1981). Based on the current channel positions, the PMF will not directly impact the pile.

B.7.2 WATERSHED

The watershed area upland of the stabilized pile area is approximately 1000 acres. The historical drainage pattern of this watershed is used in the conceptual design. The wash in which the old tailings pile currently sits will continue to divert the majority of the flood flows in the upland watershed away from the stabilized pile. The excavation of the old pile tailings will not adversely affect this drainage pattern.

A small portion of the upland watershed to the west and southwest is tributary to the stabilized pile. The flood flows from this area are considered to have an insignificant impact on the stabilized pile. This is due to the small watershed area involved and the presence of the bedrock foundation along the west and southwest edges of the pile.

The 800-acre watershed directly south of the new tailings pile is tributary to the western segment of Cane Valley Wash. Flooding from this watershed will flow past the east edge of the pile but will not directly impact the pile.

B.7.3 TOP OF PILE

A PMP event would generate sheet flows on top and sideslopes of the pile. Pile design is such that it will not promote flow concentrations on the pile. Flows on the north and west slopes of the pile will contribute to flows from the small portion upland watershed, while flows on the south and east slopes will flow around the pile and overland along the topographic gradient toward Cane Valley Wash.

B.7.4 TEMPORARY MEASURES

During construction, it will be necessary to capture and contain all runoff from contaminated areas and carry it to a retention pond. Ditch size will be designed to safely pass the peak flow resulting from a 10-year one-hour storm event. The location of the temporary ditches and evaporation pond will be determined by the RAC in the final design.
The waste-water retention pond should be sized to contain:

- The runoff from the 10-year 24-hour storm event.
- The sediment volume expected during construction.
- Equipment washdown water.
- Laundry, shower, and washbasin waste water.

In the case of the latter two requirements, the RAC shall assess and define the period for which provision to hold water will be made. In doing this, the following shall be considered: likely volumes of water; practical pond volumes; methods of disposing of excess volumes; the consequences of insufficient volume; and the relative cost of providing as compared to not having sufficient pond volume.

The RAC will prepare the final design and specify the location of the retention pond. Facilities will include an emergency spillway capable of passing the peak runoff from a 25-year one-hour precipitation event, while maintaining one foot of freeboard between the top of the embankment and the maximum water surface.

Contaminated water collected in the retention pond will be suitable for use in compacting tailings and contaminated materials only. Using water from the retention basin will reduce the time required for evaporation of water in the retention basin. A water treatment facility will be utilized if necessary to meet the criteria of no off-site discharge of contaminated surface water; however, such a facility should not be necessary.

The RAC will assess the need for further erosion control measures. To be considered are flow velocities, the erodibility of the materials exposed in the swales, and the cost of rock erosion protection.

B.7.5 GEOMORPHIC CONSIDERATIONS

A rock apron extends around the pile except where bedrock is exposed at the surface. The apron is designed according to the Technical Approach Document (DOE, 1985).

The west segment of Cane Valley Wash is a potential geomorphic hazard to the proposed embankment. Should the flood flows approach the pile and undercut the natural soils below the apron, the rock material of the apron will fall in, and create erosion protection against further undercutting.

The existing drainage channel west of the proposed site will effectively eliminate any geomorphic hazard of water flowing from the 1000-acre upland watershed.

Erosion potential of the terrain adjacent to the pile is minimal due to the low sloping topography to the north, east, and south, and the existence of exposed bedrock to the west.
B.8 EROSION PROTECTION - APRON AND PILE

B.8.1 OBJECTIVE AND SCOPE

Long-term protection against the effects of erosion is required to maintain the integrity of the pile during the design life. Three areas where erosion must be prevented are:

- Erosion of the tailings pile cover by runoff on the pile.
- Erosion of the tailings pile and adjacent areas by flooding as a result of runoff from the small watershed area west and southwest of the tailings pile.
- Erosion of the tailings pile by flood waters in Cane Valley Wash should the bottom channel of the wash migrate toward the pile.

B.8.2 EMBANKMENT ROCK SIZING

Rocks for the topslopes and sideslopes of the stabilized pile are sized to withstand the erosive forces from the PMP. The depth of flow over the rock is critical in determining the mean rock size. In order to calculate the depth of flow, the quantity of flow is calculated by:

\[ Q_T = \frac{I \times L}{43560} \]  
(Derived from rational formula \( Q = CIA \))

where

- \( Q_T \) = total runoff cfs/ft.
- \( A \) = area \((L \times W)\).
- \( I \) = the one-hour rainfall intensity corresponding to the time of concentration \((\text{inches/hours})\).
- \( L \) = length of flow \((\text{feet})\).
- \( C \) = constant \((\text{assumed equal to one})\).
- \( W \) = width \((\text{usually equal to one foot})\).

The one-hour PMP rainfall \((7.9 \text{ inches})\) is calculated using the methods described in Hydrometeorological Report No. 49 \((\text{NOAA, 1977})\).

The time of concentration \((t_c)\) is calculated from an assumed velocity and average length of flow:

\[ t_c = \frac{\text{length of flow (ft)}}{\text{velocity (fps) x 60 x 2 (min)}} \]

Minimum allowable \( t_c = 2.5 \text{ min} \).
The time of concentration is used to select the percent of the one-hour Probable Maximum Precipitation (PMP):

\[ \text{Percent of one-hr PMP} = \frac{t_c}{(0.0089 \times t_c + 0.0686)} \]

The intensity is calculated using the formula:

\[ I = \text{PMP} \left( t_c \right) \times \frac{60}{t_c} \]

where

- \( I \) = the one-hour rainfall intensity corresponding to the time of concentration (inches/hour).
- \( \text{PMP} \left( t_c \right) \) = the incremental rainfall amount for the time of concentration.
- \( t_c \) = time of concentration (minutes).

Table B.8.1 contains the values for the percent of the one-hour PMP, the time of concentration, and the unit flows for specific areas of the pile.

<table>
<thead>
<tr>
<th>Location</th>
<th>Time of concentration (minutes)</th>
<th>Intensity distribution (percent)</th>
<th>Equivalent 1-hr intensity (inches/hr)</th>
<th>Unit flow (cfs/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top and sideslope</td>
<td>2.5</td>
<td>27.5</td>
<td>52.14</td>
<td>0.78</td>
</tr>
</tbody>
</table>

A computer program has been developed for the Safety Factor Method (OOE, 1985). The program provides depth of flow, velocity, and D50 rock size for a specified quantity of flow over the rock. If this velocity and the estimated velocity used to calculate the time of concentration are within 10 percent there is no need to iterate; if not, the iterative process is continued by replacing the estimated velocity with the calculated velocity until the two velocities are within 10 percent.

Based on the above procedures, Table B.8.2 gives possible sizes for the rock for erosion protection materials for the topslope, sideslopes, and apron. Suitable filter layers will be placed as required to prevent piping or erosion of the various layers in the radon and erosion barrier system.
Table B.8.2 Rock protection requirements for pile

<table>
<thead>
<tr>
<th>Location</th>
<th>Rock size requirements (inches)</th>
<th>Layer(^a) thickness (ft)</th>
<th>Flow(^b) (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top and sideslope</td>
<td>(4 \leq D_{50} \leq 6)</td>
<td>1.0</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>(8 \leq D_{100} \leq 12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toe protection</td>
<td>(4 \leq D_{50} \leq 6)</td>
<td>3.0</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(8 \leq D_{100} \leq 12)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)A six-inch sand bedding layer and a six-inch rock filter layer will be required in addition to the rock erosion protection layer.

\(^b\)Flows account for interstitial flow.

B.8.3 ROCK SIZING (due to off-pile runoff)

The rock size required for protection of the sideslopes and toe of the pile was determined using methods discussed in the DOE Technical Approach Document (DOE, 1985). Preliminary estimates of a PMF on the pile would require rock size of \(D_{50} = 4\) inches. Current surface drainage patterns indicate that further erosion protection is not required due to the PMF in Cane Valley Wash. The on-pile PMF is the controlling factor in determining rock size.

B.8.4 GRADED FILTERS

A graded filter will be required between the radon barrier and the erosion barrier. This will be designed in accordance with requirements specified in the Technical Approach Document (DOE, 1985).
B.9 WATER SUPPLY FOR REMEDIAL ACTION

There are three old production wells located near the tailings (618, 619, and 625). These wells have not shown any contamination to date. However, due to the proximity of the wells to the tailings and contaminant plumes, a potential for the cone of depression to intercept contaminated ground water during pumping exists. Water from these wells can be withdrawn and used for on-site activities such as compaction of the tailings.

A potable water supply should be developed upgradient of the tailings. The most likely source of dependable good quality water is the DeChelly Sandstone Aquifer. The DeChelly well should be developed far enough away from the tailings to prevent pumping any contaminated ground water. This distance was determined using the Theis equations (Johnson, 1975):

\[ s = \frac{Q}{4\pi T} W(u) \quad \text{and} \quad u = \frac{r^2 S}{4Tt} \]

where

- \( s \) = drawdown at a given distance from the pumped well.
- \( Q \) = pumping rate.
- \( T \) = transmissivity.
- \( W(u) \) = the well function.
- \( r \) = distance from the pumping well.
- \( S \) = storage coefficient.
- \( t \) = time since pumping began.

The following inputs were used to calculate \( r \), the distance from the pumping well:

- **s** - The objective is to calculate \( r \), the distance from the pumping well, where drawdown is negligible, therefore, a very small drawdown of 0.01 foot was assumed.

- **Q** - A pumping rate of 50 gal/min was assumed to supply adequate water for remedial action purposes.

\[ 50 \text{ gal/min} \times 60 \text{ min/hr} \times 24 \text{ hr/day} = 72,000 \text{ gal/day} \times 1 \text{ ft}^3/7.48 \text{ gal} = 9625 \text{ ft}^3/\text{day}. \]

- **T** - Coefficients of transmissibility reported in Cooley et al. (1969), for the DeChelly Sandstone were 310 to 755 gal per day per foot. The maximum \( r \) results from maximum \( T \), so 755 qpd/ft was used to give a conservative estimate of \( r \).

\[ 755 \text{ ga/day/ft} \times 1 \text{ ft}^3/7.48 \text{ gal} = 100 \text{ ft}^3/\text{day per ft}. \]

- **S** - Cooley et al. (1969) report porosity ranges for the DeChelly Sandstone as 0.14 to 0.27. The maximum \( r \) results from the minimum \( S \), therefore 0.14 was used for \( S \). This is a minimum value of \( S \) because it does not account for elastic effects of the confined aquifer.
t - Time since pumping began, r was calculated for a one-year time period, and for a two-year time period. One year represents the approximate time that water will be pumped for remedial action; two years gives a conservative estimate, in the event that remedial action takes longer than planned. Rearranging equation

\[ s = \frac{Q}{4\pi T} W(u) \]

yields:

\[ W(u) = \frac{Q S4\pi T}{72,000 \text{ gpd}} \]

from Johnson, 1975

at \( W(u) = 0.0013 \), \( u = 4.9 \)

\[ u = \frac{r^2 S}{4Tt} = \frac{u4Tt}{S} \]

\[ r = \sqrt{\frac{4.9 \times 4 \times 100 \text{ ft}^3/\text{day/ft} \times 365 \text{ days}}{0.14}} = 2260 = 0.43 \]

with \( t = 730 \text{ days (2 years)} \), \( r = 0.61 \text{ mile} \).
B.10 RESTORATION

B.10.1 DESIGN REQUIREMENTS

Areas disturbed during the remedial action process for the Monument Valley site shall be regraded, if necessary, to provide positive drainage. These areas will be revegetated by reseeding.

B.10.2 BORROW SOURCE AND MATERIAL PROPERTIES

No borrow materials are necessary for site restoration.

B.10.3 PLACEMENT CRITERIA

Areas disturbed during remedial action should be regraded and compacted as needed to promote positive drainage and to maintain competent terrain.

B.10.4 MATERIAL QUANTITIES

Areas disturbed during remedial action were estimated based upon known limits of contamination, design volumes of cover materials, and drainage requirements. The areas shown in Table B.10.1 may be used to estimate areas to be regraded.

Table B.10.1 Areas of restoration

<table>
<thead>
<tr>
<th>Item</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing site</td>
<td>80</td>
</tr>
<tr>
<td>Radon cover borrow site</td>
<td>17a</td>
</tr>
<tr>
<td>Erosion protection borrow site</td>
<td>b</td>
</tr>
</tbody>
</table>

*aAssuming a five-foot depth of excavation.

bRestoration work at the erosion protection borrow site will be covered in the HAT dRAP.

B.10.5 REVEGETATION

Revegetation will be accomplished at the Monument Valley site and the borrow sites by reseeding.
BIBLIOGRAPHY FOR APPENDIX B


APPENDIX C

RADIOLOGICAL SUPPORT PLAN
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</table>
C.1 INTRODUCTION

The Uranium Mill Tailings Radiation Control Act of 1978 (PL95-604) gave the responsibility of developing standards for remedial action to the Environmental Protection Agency (EPA). Section 108 of PL95-604 states that the DOE shall "select and perform remedial actions at the designated processing sites and disposal sites in accordance with the general standards" prescribed by the EPA. The EPA standards state:

"Section 108 of the Act requires the Secretary of Energy to select and perform remedial actions 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 affected Indian Tribes and the Secretary of the Interior. These parties, in their respective roles under Section 108, are referred to hereafter as 'the implementing agencies.'"

The implementing agencies shall establish methods and procedures to provide 'reasonable assurance' that the provisions of Subparts A and B are satisfied. This should be done primarily through use of analytical models, in the case of Subpart A, and for Subpart B through measurements performed within the accuracy of currently available types of field and sampling procedures. These methods and procedures may be varied to suit conditions at specific sites."

Subpart B consists of standards for cleanup of land and buildings. The standards applicable to the project are:

"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 an 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 microR/h."
In addition to the EPA standards for buildings, removable surface alpha contamination shall not exceed 1000 dpm/100 cm², and the total non-removable alpha contamination shall not exceed 5000 dpm/100 cm². This limit will ensure that potential airborne radionuclide concentrations will not exceed 10 CFR Part 20 Appendix B standards and that physical contact with the surfaces by occupants of the structures will not result in a measurable radiation exposure.

As indicated earlier, the standards suggest that the implementing agencies determine what methods and procedures will be used to provide "reasonable assurance" that the standards are met. Reasonable assurance implies that a site-specific analysis is appropriate where the cost of demonstrating compliance with the standards is to be weighed against the health risks or other impacts associated with leaving areas which slightly exceed the standards.

The sections which follow provide the procedures proposed for use at the Monument Valley site. Consideration was given to the time required to collect samples and perform the analyses.
C.2 BASIS FOR RADIOLOGICAL SURVEY STRATEGY

The Monument Valley site consists of the tailings piles, pond area, heap leach area, ore storage areas, rubble piles, and roads. Excavations will range from removal of surficial contamination to several feet in depth. Except for backfill required to provide an appropriate drainage pattern, backfilling of excavated areas will not be needed. For most of the excavated area, residual contamination should not exceed 5 pCi/g of Ra-226 above the naturally present concentration. Based on the EPA standards cited above, an area average concentration from 100 square meters will be used.

In areas where backfilling to grade is required, uncontaminated fill will be used and will minimize the potential health effects due to slight residual contamination. In these areas EPA standards allow 15 pCi/g of residual Ra-226 if the backfill is at least six inches thick.

All foundations on the Monument Valley site will be demolished and buried. No building decontamination or verification measurements will be required.
C.3 REMEDIAL ACTION RADIOLOGICAL SURVEY PLAN

Radiological surveys are performed for three purposes: site characterization, excavation control, and final radiological verification. Site characterization surveys or pre-remedial action surveys are performed to identify volumes of material which exceed the standard. The results are used for planning and engineering design. Excavation control monitoring is performed as the work is being done to guide and control the amount of contaminated material removed. Finally, when excavation control monitoring results indicate that there is a high probability that the area meets the standards, a final radiological survey is carefully performed and the results documented.

C.3.1 SITE CHARACTERIZATION SURVEYS

Field sampling programs conducted by Bendix Field Engineering Corporation (BFEC) have been used to identify the subsurface boundary of the tailings pile, as well as the depth and area of the former mill yards, ore storage, pond area, and windblown contaminated areas. Subsurface evaluations were performed using gamma well logging techniques and by analyzing cores from boreholes. In general, boreholes and surface measurements and samples were made on grids ranging from 100 by 100 feet to 200 by 300 feet. Additional measurements were performed in areas of radiological interest. The grid points have been identified by a land survey tied to a state plane survey point and all recordable data were located by these coordinates.

C.3.2 EXCAVATION CONTROL MONITORING

The purpose of excavation control monitoring is to guide excavation through the use of real-time radiological measurements. It is designed to ensure that the 5 pCi/g (surface) and 15 pCi/g (subsurface) standards are met. In addition, it minimizes the possibility that material meeting the standards is also excavated. Properly performed excavation control monitoring simultaneously ensures that neither under-excavation nor over-excavation occurs.

Excavation will be monitored by qualified technicians relying principally on gamma field measurements employing hand-held instruments such as gamma-scintillation detectors. This technique will only be used where measurements are not seriously impaired by interference from nearby tailings deposits. In areas where significant interference exists, alternate monitoring techniques will be used. These techniques may include use of a shielded probe gamma-scintillation instrument (operated in a gross count mode or in a delta mode) or the immediate counting of soil samples. In all cases, these techniques will be routinely calibrated by comparison of the field measurements to soil samples analyzed in the laboratory and reported on a fully equilibrated dry-weight basis. Because the standards are based upon average areas of 100 m², the excavation control monitoring will be performed on areas of this characteristic size as well.
Elevated gamma-ray radiation fields will preclude exclusive use of in-situ monitoring devices to estimate the surface radionuclide concentrations in soil on or immediately adjacent to the tailings pile. When in-situ measurements cannot be performed, the suggested method for analysis is to take individual or composite samples of soil, seal by canning, and immediately count the sample by gamma-ray spectrometry. Errors associated with this approach will be reduced by taking several samples 30 days prior to starting work to determine calibration factors. These samples will be counted, dried, pulverized, and screened with recanning for subsequent analysis. They will be counted later after the Ra-226 daughters reach equilibrium. Analyses of these prepared samples can then be compared to standards. Several samples will be collected weekly during the remedial action and analyzed to provide a measure of the variation of the calibration factor.

C.3.3 BUILDING DECONTAMINATION CONTROL MONITORING

No buildings remain on the Monument Valley site.

C.3.4 FINAL RADIOLOGICAL VERIFICATION SURVEY FOR LAND

The final radiological survey will be based on 100 m² areas, with a composite sample used to obtain a measure of the average Ra-226 concentration in an area. The radium measurement will be reported on a dry-weight basis. For measurements based on gamma spectrometry of radium daughters, full equilibrium will be assured. It is expected that at least preliminary measurement results will be obtained prior to backfilling. The error limits for Ra-226 verification measurement techniques must be better than plus or minus 30 percent, at the 95 percent confidence level.

The average Ra-226 concentration on each 100 m² area which is surveyed will be determined by a composite sample composed of a number of 15-cm-deep samples of approximately equal mass taken on a uniform spacing over the survey area. Nineteen to 24 samples is an appropriate number for forming the composite, but fewer may be used if shown to be sufficient to characterize the mean concentration and if approved in advance by the UMTRA Project Office. The sampling error associated with composite sampling should be routinely estimated by collection of duplicate samples (two to five percent pair-wise basis) with the same number of samples forming each composite.

In large areas of relatively uniform contamination (windblown) it may not be necessary to measure every 100 m² area to provide reasonable assurance that the entire excavation area meets the EPA standards. A statistically sound program of sampling a subset of all 100 m² areas may be feasible, but will require demonstrations prior to implementation, and approval from the UMTRA Project Office. Such a program will be applied only to large areas where residual contamination is
low and expected to be very uniform (i.e., windblown areas, and the like). In the absence of an approved program, every 100 m$^2$ area will be verified.
C.4 DATA AND SAMPLE MANAGEMENT

During the cleanup operations, the Remedial Action Contractor will collect data to support excavation control. Data used in declaring an area adequately decontaminated will be documented in a format approved by the UMTRA Project Office.

Site characterization survey data, excavation control data, and the final radiological survey data will be collected using procedures and analytical methods meeting the requirements of the UMTRA Project Quality Assurance Program Plan (UMTRA-DOE/AL-400325). All data used in describing the final radiological condition of the site as well as other data as specified by the UMTRA Project Office will be provided in a convenient format. Data generated in the remedial action will be presented in a report documenting the final radiological condition of the property. Verification samples will be archived pending orders for transfer or disposal from the UMTRA Project Office.
C.5 CERTIFICATION

Certification is a professional judgement by an independent party that the remedial action has been completed according to the site-specific Remedial Action Plan and meets the applicable standards.

During the remedial action operations, the Remedial Action Contractor will make available to appropriate state agencies, Federal agencies, or UMTRA Project-designated contractors data related to the cleanup. In addition, samples collected during the cleanup operations may be split for analyses by these agencies to allow comparison of analytical results. These data, along with any additional data collected at the discretion of the certifying agent, will be used in the final certification report.