1 of 1

REMEDIAL ACTION PLAN AND SITE DESIGN FOR STABILIZATION OF THE INACTIVE URANIUM MILL TAILINGS SITES AT SLICK ROCK, COLORADO

REMEDIAL ACTION SELECTION REPORT

Draft

July 1993

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OF THE INACTIVE URANIUM MILL TAILINGS SITES
AT SLICK ROCK, COLORADO**

Draft

July 1993

**Prepared for
U.S. Department of Energy
UMTRA Project Office
Albuquerque, New Mexico**

EXECUTIVE SUMMARY

INTRODUCTION

The Slick Rock uranium mill tailings sites are located near the small town of Slick Rock, in San Miguel County, Colorado. There are two designated UMTRA sites at Slick Rock, the Union Carbide (UC) site and the North Continent (NC) site. Both sites are adjacent to the Dolores River. The UC site is approximately 1 mile (mi) [2 kilometers (km)] downstream of the NC site. Contaminated materials cover an estimated 55 acres (ac) [22 hectares (ha)] at the UC site and 12 ac (4.9 ha) at the NC site. The sites contain former mill building concrete foundations, tailings piles, demolition debris, and areas contaminated by windblown and waterborne radioactive materials. The total estimated volume of contaminated materials is approximately 620,000 cubic yards (yd³) [470,000 cubic meters (m³)]. In addition to the contamination at the two processing site areas, four vicinity properties were contaminated. Contamination associated with the UC and NC sites has leached into groundwater.

REMEDIAL ACTION

Pursuant to the requirements of the Uranium Mill Tailings Radiation Control Act (UMTRCA), the proposed remedial action plan (RAP) will satisfy the U.S. Environmental Protection Agency (EPA) standards (40 CFR 192) for cleanup, stabilization, and control of the residual radioactive materials (RRM) tailings and other contaminated materials] at the proposed disposal site at Burro Canyon. The requirements for control of the RRM (Subpart A) will be satisfied by the construction of an engineered disposal cell.

The proposed remedial action will consist of relocating of the uranium mill tailings, contaminated vicinity property (VP) materials, demolition debris, and windblown/waterborne materials to a permanent repository at the proposed Burro Canyon disposal cell. The site is located approximately 5 road mi (8 km) northeast of the mill sites on land currently administered by the U.S. Bureau of Land Management. The proposed disposal site was selected based on public input, environmental considerations, and regulatorily acceptable design opportunities.

The proposed disposal cell will be partially belowgrade. An 8-foot (ft) [2.4-meter (m)] clay liner will be placed on the sideslopes of the excavated cell to act as a seepage barrier. The purpose of the barrier will be to prevent seepage from the cell entering the sandstone stringers in the Dakota Sandstone Formation and then leaving the site or developing surface expressions. The RRM will be covered with a 4.5-ft (1.3-m)-thick cover that will include a radon/infiltration barrier, layers to protect the barrier against frost penetration and the buildup of moisture, a sand and gravel bedding/drainage layer, and a rock erosion protection layer at the surface of the cell.

DESIGN ANALYSES

This proposed RAP incorporates the results of detailed investigation of geologic, geomorphic, and seismic conditions at the proposed disposal site. The proposed disposal

site will be geomorphically stable (*i.e.*, against gully erosion in the cell vicinity, or from slope failure). Seismic design parameters were developed for the geotechnical analyses of the proposed cell. Cell stability was analyzed to ensure long-term performance of the disposal cell in meeting design standards, including slope stability, settlement, and liquefaction potential.

The proposed cell cover and erosion protection features were also analyzed and designed to protect the RRM against surface water and wind erosion. The location of the proposed cell precludes the need for permanent drainage or interceptor ditches. Rock to be used on the cell top-, side-, and toeslopes was sized to withstand probable maximum precipitation events.

The requirements for radon emissions of 40 CFR 192, Subpart A, will be met with the disposal cell's 2-ft (0.6 m)-thick fine-grained radon barrier.

GROUNDWATER COMPLIANCE

To achieve compliance with the proposed EPA groundwater protection standards, the U.S. Department of Energy (DOE) proposes a supplemental standard that will ensure protection of human health and the environment. This standard applies to the groundwater in the uppermost aquifer, defined as the low-yield groundwater in the upper sandstone unit of the Burro Canyon Formation. The proposed disposal cell foundation will be separated from the uppermost aquifer by a thick layer [25 to 75 ft (8 to 23 m)] of low-permeability mudstone. Groundwater in the underlying lithologic units is protected from potential site-related contamination by low-permeability mudstone/claystone units and upward vertical hydraulic gradients that inhibit the downward migration of water. This supplemental standard will be narrative and will not include numerical concentration limits for the hazardous constituents identified in the RRM at the Slick Rock sites. In addition, a point of compliance has not been proposed. Groundwater monitoring would not be effective at the Burro Canyon disposal site, and is therefore not proposed, because insufficient yield in the uppermost aquifer will preclude its future use. The only point of exposure that could potentially affect human health or the environment would be surface seepage at the base of the disposal cell mesa. In lieu of groundwater monitoring, DOE will conduct compliance monitoring through inspections to locate surface expressions of seepage at and in the vicinity of the Burro Canyon disposal site. These visual inspections will include looking for physical evidence of mineralization, phreatophyte vegetation, and the presence of saturated zones at sandstone outcrops.

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ATTACHMENT 2	GEOLOGY REPORT
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LIST OF ACRONYMS AND ABBREVIATIONS

<u>Acronym</u>	<u>Definition</u>
ac	acre
ALARA	as low as reasonably achievable
ASTM	American Society for Testing and Materials
CDH	Colorado Department of Health
cm	centimeter
DOE	U.S. Department of Energy
EA	environmental assessment
EPA	U.S. Environmental Protection Agency
FE	floating earthquake
ft	feet
ft ³ /s/ft	cubic feet per second per foot
ft/yr	feet per year
g	gravity
g/cm ³	grams per cubic centimeter
gpd	gallons per day
ha	hectare
hr	hour
in	inch
km	kilometer
L/s	liters per second
m	meter
m ²	square meter
m ³	cubic meter
m ³ /s/m	cubic meter per second per meter
MCL	maximum concentration limits
ME	maximum earthquake
mi	mile
μg/L	micrograms per liter
μR/hr	microrentgen per hour
MSL	mean sea level
NC	North Continent
NRC	U.S. Nuclear Regulatory Commission
pCi/g	picocuries per gram
pCi/L	picocurie per liter
pCi/m ² s	picocuries per square meter per second
PHA	peak horizontal acceleration
PMP	probable maximum precipitation
POC	point of compliance
QA	quality assurance
QC	quality control
Ra	radium
RAC	Remedial Action Contractor
RAP	remedial action plan
RAS	remedial action selection

LIST OF ACRONYMS AND ABBREVIATIONS (Concluded)

<u>Acronym</u>	<u>Definition</u>
Rn	radon
RRM	residual radioactive materials
SF&C	standard format and content
SPEAR	Software Program for Environmental Analysis and Reporting
SRP	standard review plan
T _c	time of concentration
TAC	Technical Assistance Contractor
TAD	<i>Technical Approach Document</i>
TDS	total dissolved solids
TER	technical evaluation reports
Th	thorium
UC	Union Carbide
UMETCO	Union Carbide Corporation
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act
yd ³	cubic yards
yr	year

1.0 INTRODUCTION

The inactive uranium mill tailings sites near Slick Rock, Colorado, were designated as 2 of 24 abandoned uranium tailings sites to be remediated by the U.S. Department of Energy (DOE) under the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. The UMTRCA requires that the U.S. Nuclear Regulatory Commission (NRC) concur with the DOE's remedial action plan (RAP), and certify that the remedial action complies with the standards promulgated by the U.S. Environmental Protection Agency (EPA). The RAP, which includes this remedial action selection (RAS) report, has been developed to serve a twofold purpose. First, it describes the activities proposed by the DOE to accomplish long-term stabilization and control of residual radioactive materials (RRM) at the inactive uranium processing sites near Slick Rock, Colorado. Second, this document and the remainder of the RAP, upon concurrence and execution by the DOE, the state of Colorado, and the NRC, will become Appendix B of the Cooperative Agreement between the DOE and the state of Colorado.

The DOE objective in preparing this RAP is to comply with EPA regulations in Subparts A through C of 40 CFR 192. All remedial action planning and design considerations contained herein reflect the incorporation of this regulatory guidance. Therefore, by performing all remedial action activities in accordance with the design presented in this RAP, the DOE will meet the standards of 40 CFR 192. These regulations are summarized in the following section of this document.

1.1 EPA STANDARDS

As required by Title I of the UMTRCA, remedial action at the Slick Rock sites must comply with regulations established by the EPA in 40 CFR 192, Subparts A through C. The regulations are summarized as follows:

- The disposal site shall be designed to stabilize and control the tailings and other RRM for 1000 years (yr) to the extent reasonably achievable and, in any case, for at least 200 years [40 CFR 192.02(b)].
- The disposal site design shall prevent radon-222 (Rn-222) flux from RRM into the atmosphere from exceeding 20 picocuries per square meter per second (pCi/m²s), or from increasing the annual average concentration of Rn-222 in air by more than 0.5 picocurie per liter (pCi/L) [40 CFR 192.02(b)].
- The remedial action shall be conducted to provide reasonable assurance that the concentration of radium-226 (Ra-226) in land, averaged over 100 square meters (m²), does not exceed the background level by more than 5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) of soil below the surface; and 15 pCi/g averaged over 15-cm-thick layers of soil more than 15 cm below the surface, as a result of any residual radioactive materials at any designated processing site [40 CFR 192.12(a)].

In September 1985, the U.S. Tenth Circuit Court of Appeals remanded the groundwater standards contained in 40 CFR 192.2(a)(2)-(3). The court stipulated that the EPA promulgate new groundwater standards of a general nature applicable to all Title I uranium mill sites.

In September 1987, the EPA issued proposed standards in response to the court remand. These proposed standards apply to disposal of the tailings (Subpart A), cleanup of groundwater contaminated by the former mills (Subpart B), and implementation of the remedial action (Subpart C).

1.2 SITE AND PROPOSED ACTION

1.2.1 History

The Slick Rock tailings sites consist of two tailings piles: one each at the Union Carbide (UC) site and the North Continent (NC) site. Both sites are presently owned by the Union Carbide Corporation (UMETCO). The UC mill began operation in 1957, and processed ore mined from the surrounding area. Upgraded material from the UC site was trucked to the UC mill in Rifle, Colorado. The NC mill site dates to 1931, when it was owned by Shattuck Chemical Company. The Federal government acquired control of the site through the Union Mines Development Corporation with the specific purpose of supplying uranium and vanadium for the Manhattan Project. UMETCO became the owner of the site in 1957. Except for some concrete foundations, all the mill buildings have been removed from the UC site. The former recreational building and dormitory remain adjacent to the site. Mobile homes have been removed from a trailer park area off the site, leaving concrete pads. All structures (including foundations) have been removed from the NC site. Both tailings piles were covered with soil and are at least partially vegetated.

1.2.2 Location

Both the UC and NC tailings sites are located in San Miguel County, Colorado, (Figure 1.1). The tailings sites are next to the Dolores River and are surrounded by steep, juniper-covered hillsides and cliffs of the Dolores River Canyon. The tailings sites are 5500 feet (ft) (1680 m) above mean sea level (MSL), while the surrounding hillsides reach 6500 ft (1980 m) above MSL. The UC tailings site is approximately 1 mile (mi) [1.6 kilometers (km)] downstream of the NC tailings site.

The sites are arid with a mean annual precipitation of 9 inches (in) (23 cm). The dominant land use in the area is grazing. A gas sweetener plant is adjacent to the UC tailings pile. In the past, mining was common in the area and there are now numerous abandoned mines and mining roads in the area. The area is sparsely populated; six people live within 1.6 mi (2.6 km) of the site.

1.2.3 Contaminated materials

The UC tailings site consists of the tailings pile, mill site, mill site demolition debris, and windblown/waterborne contaminated areas (Figure 1.2). In addition, a small area [1.5 acres (ac)] [0.6 hectare (ha)] within the UC-designated site is the site of a radium mill operated for Madame Curie around the turn of the century. The tailings pile and the surrounding contaminated land cover 55 ac (22 ha). Approximately 536,000 cubic yards (yd³) (410,000 m³) of contaminated material at the UC site are distributed as shown in Table 1.1.

Table 1.1 Contaminated material volumes at the Slick Rock processing sites, Colorado

Location/source	Volume	
	(yd ³)	(m ³)
UC Site		
Tailings	296,000	226,000
Contaminated materials	237,500	181,600
Demolition debris	2,850	2,180
Subtotal	536,350	409,780
NC Site		
Contaminated soil/tailings	84,800	64,800
Demolition debris	155	119
Subtotal	84,955	64,919
Totals	621,305	474,699

The NC tailings site consists of the tailings pile and windblown contaminated areas (Figure 1.3). The tailings pile is difficult to differentiate from the surrounding contaminated land. Approximately 12 ac (4.9 ha) are contaminated, with approximately 85,000 yd³ (65,000 m³) of contaminated materials distributed as shown in Table 1.1.

1.2.4 Remedial action

The proposed remedial action consists of removing all contaminated material from both former mill sites to the proposed Burro Canyon disposal site, located approximately 2.5 mi (4.0 km) east of the UC and NC processing sites in Sections 21 and 28, Township 44 North, Range 18 West (Figure 1.4). Contaminated materials will be transported over an approximately 6-mi (10-km) haul route. The approximately 1-mi (1.6-km) access road from Colorado State Highway 141 to the Burro Canyon disposal site will require upgrading, as will the access road between the NC site and Highway 141. The remainder of the haul route is on state- and county-maintained roads.

Figures 1.5 and 1.6 present the proposed disposal cell. Disposal will consist of constructing a 12-ac (4.9-ha) engineered cell partially belowgrade. The disposal

FIGURE 1.2
LOCATION OF THE UNION CARBIDE
UMTRA SITE NEAR SLICK ROCK, COLORADO

FIGURE 1.3
LOCATION OF THE NORTH CONTINENT
UMTRA SITE NEAR SLICK ROCK, COLORADO

FIGURE 1.4
BURRO CANYON SITE LOCATION

SECTION

A
0-14

cell will be situated to optimally utilize the saddle and mesa topography at the Burro Canyon site. The cell will be shaped to avoid or minimize detrimental effects of surface water drainage and potential geomorphic change. To this end, the edge of the tailings and contaminated materials in the disposal cell will be no closer than 100 ft (30 m) to the edge of the mesa, nor extend outside the perimeter shown in Figure 1.5.

The disposal cell will hold approximately 620,000 yd³ (470,000 m³) of contaminated material, and cover an area approximately 610 ft (190 m) wide and 900 ft (280 m) long. The height of the cell will range from 30 ft (9 m) to 50 ft (15 m) above the existing ground surface. The disposal cell footprint will be excavated to prepare for emplacement of the contaminated materials. An 8-ft (2.4-m) clay liner will be placed on the sideslopes of the excavated cell to act as a seepage barrier. Some of the excavated materials will be used as fill along the embankment sides and for the upper portion of the cover. The remaining excavated material will be left on the site.

All contaminated materials will be covered with a 2-ft (0.6-m)-thick layer of fine-grained materials that will constitute a radon barrier to prevent release of radon into the atmosphere. A 2-ft (0.6-m)-thick frost protection layer of fine-grained material will be placed over the radon barrier, and then a 6-in (15-cm) sand and gravel bedding layer. The top of the cover will consist of riprap ranging in depth from 8 to 12 in (20 to 30 cm). The disposal cell will have a 2-percent topslope and 25-percent sideslopes. The completed disposal cell will occupy an area of 12 ac (4.9 ha). A buffer area of 53 ac (21 ha) will bring the total final disposal site to 65 ac (26 ha).

The remedial action is expected to take 19 months. During the summer of the first year, the sites will be prepared, the existing dirt road upgraded, the disposal cell excavated, existing foundations demolished, the clay liner constructed, and contaminated materials from the UC and NC sites excavated and placed. A 3- to 5-month winter shutdown will be scheduled. The second-summer activities will include collecting cover materials from the Dolores River and Disappointment Valley borrow sites and constructing the cover system. Final site grading and site restoration will also be performed.

Detailed drawings of the disposal cell facility are shown in Attachment 1, Drawing Nos. SRK-0-10-0330 through SRK-DS-10-0338.

After the contaminated materials are removed, the processing sites will be restored with uncontaminated fill obtained from the disposal cell excavation and revegetated or mulched. After remedial action, the processing site eventually will be released for use consistent with existing land use controls.

1.3 SCOPE AND CONTENT

This RAS report has been structured to provide a brief but comprehensive description of the remedial action proposed for the Slick Rock sites. Data and

supporting information generated for this remedial action are too extensive to be incorporated into this single document, although pertinent information and data are included, as are references to supporting documents. The RAP consists of this RAS and the following attached reports, which describe various aspects of the remedial action in more detail:

- Attachment 1, Specifications, Design Drawings, Information for Reviewers, Information for Bidders (6 volumes), Calculations and Reports (4 volumes), and Cost Estimates (1 volume).
- Attachment 2, Geology Report.
- Attachment 3, Groundwater Hydrology Report.
- Attachment 4, Water Resources Protection Strategy.

1.4 REMEDIAL ACTION SELECTION ORGANIZATION

Sections 2.0 through 6.0 are organized by technical discipline. The approach adopted in the RAS report is similar to that adopted by the NRC for site technical evaluation reports (TER). This RAS report is formatted in accordance with the requirements of NRC standard format and content (SF&C) guide (NRC, 1989) for remedial action selection for Uranium Mill Tailings Remedial Action (UMTRA) Project sites. The RAS report has been compiled to facilitate NRC preparation of its TERs. The RAS report does not contain design details. These are available in supporting documents, reports, drawings, specifications, and calculations (see Attachment 1).

Table 1.2 summarizes the relationship between design details and criteria and supporting calculations and reports.

1.5 COLLATERAL DOCUMENTS

The *Environmental Assessment of Remedial Action at the Slick Rock Sites* (DOE, 1993) describes existing conditions at the sites, the proposed remedial actions and alternatives, and the environmental impacts of the proposed action. It also includes environmental details not reported in this RAP.

An additional supporting document is the *Technical Approach Document* (TAD) (DOE, 1989a), which describes technical approaches and procedures used on the UMTRA Project. The TAD also includes discussions of major technical areas, design considerations, surface water hydrology and erosion control, geotechnical aspects of pile design, radiological issues (the design of the radon barrier, in particular), and protection of groundwater resources. Copies of these documents, as well as supporting data and calculations, are on file in the UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Table 1.2 Relationship between design details, criteria, and supporting calculations

Design detail	RAP attachment calculation number	Title	Remarks
Tailings and contaminated material volumes	11-212-01-01	NC and UC site contaminated material - excavation quantities.	Volume totals presented in Table 1.1 of RAS.
Pile location	11-205-01-02	Demolition debris - quantity estimate.	The tailings and other contaminated materials will be relocated and consolidated into a new disposal cell at Burro Canyon site. A 20-ft-wide rock apron will protect the integrity of the embankment side slope.
	11-322-02-00	Erosion protection - embankment toe apron.	
Disposal cell layout and surface water	11-209-01-01	Site hydrology - rainfall, depth, intensity, duration, and frequency relations.	The tailings and other contaminated materials will be consolidated in Burro Canyon disposal cell and contoured to sideslopes of 25% and topslopes of 2%. The cell will be partially belowgrade. Site will be graded to drain and divert surface runoff away from pile.
			Uncontaminated excavated material will be disposed of in a separate spoil pile located near the disposal embankment.
Site restoration	11-330-01-00	Site restoration - earthwork quantities and seeding.	Restored to positive drainage and reseeded with acceptable seed mixtures.
Geomorphology	RAP Attachment 2	Geology Report.	The edge of the tailings and contaminated materials in the disposal cell will be no closer than 100 ft to the edge of a scarp that forms the disposal site.
Seismicity	RAP Attachment 1, Reports	Site seismicity and design earthquake criteria.	$M_b = 6.2$, 9.3 mi from site, peak acceleration = 0.21 g.
	RAP Attachment 2	Geology Report.	

Table 1.2 Relationship between design details, criteria, and supporting calculations (Concluded)

Design detail	RAP attachment calculation number	Title	Remarks
Erosion protection	11-322-01-00	Erosion protection - embankment top and side slopes.	Riprap sizes and layer thickness were determined.
	11-322-02-00	Erosion protection - embankment toe apron.	
	11-322-03-00	Erosion protection - gradations and layer thickness.	
	11-231-02-02	Erosion protection - rock quality evaluation.	
Radon/infiltration barrier	11-275-01-00	Radon barrier design - statistical analysis of Ra-226 concentration data.	Design thickness of 2 ft will limit radon flux to meet EPA criteria. Permeability will be less than 10^{-7} cm/s.
	11-321-01-00	Radon barrier design - RAECOM input data.	
	11-321-02-00	Radon barrier design - design thickness.	
Geotechnical	11-250-04-03	Embankment design - embankment material properties.	Properties used in stability and cover cracking analysis.
	11-321-03-00	Cover design - frost penetration depth.	Frost penetration layer was provided.
	11-323-01-00	Embankment design - settlement and cover cracking analysis.	Based on a simplified approach, there is potential for cover cracking at north edged of the pile.
	11-320-01-00		The factor of safety exceeds minimum requirement.
Groundwater	RAP Attachment 3	Groundwater Hydrology Report.	
	RAP Attachment 4	Water Resources Protection Strategy.	Narrative supplemental standard.
g - Gravity. cm/s - Centimeters per second.			

2.0 GEOLOGIC STABILITY

This section documents that, at the Burro Canyon site, the DOE has adequately characterized the impact of geologic conditions on the long-term performance objectives of remedial action as defined by 40 CFR 192.02.

The EPA standards listed in 40 CFR 192 do not include generic or site-specific requirements for characterization of the geological conditions at UMTRA Project sites. Rather, 40 CFR 192 requires that controls must be effective for 1000 yr to the extent achievable, and in any case for at least 200 yr. To achieve this long-term stability, certain geologic performance objectives must be met. For example, the NRC standard review plan (SRP) (NRC, 1985) requires information about basic regional and site geology and site stratigraphy. This information is the basis of the geotechnical and groundwater aspects of disposal cell performance evaluation, described in Sections 3.0 and 5.0 of this document. An evaluation of the potential geomorphic hazards is required, and the DOE should show that potential geomorphic change will not affect the site or the disposal cell integrity throughout its design life. The site geological characterization should estimate earthquake-induced ground accelerations that could occur at the site, as well as the potential for other types of tectonic hazards that could affect the performance of the disposal cell. Geological site characterization must also demonstrate that future resource development will not adversely affect the disposal cell's stability during the design life. Additional criteria that support an evaluation of the adequacy of the site, regional geology, and the basis of the work described herein are in the DOE TAD (DOE, 1989a).

2.1 SCOPE OF WORK

Detailed investigations of geologic, geomorphic, and seismic conditions at the site were conducted by the Technical Assistance Contractor (TAC). Geologic investigations were carried out in accordance with the procedures and approaches described in the TAD (DOE, 1989a) to gather the data specified in the NRC SRP and SF&C guide. These investigations included the compilation and analysis of previously published and unpublished geological literature and data; review and analysis of historical and instrumental seismic data; geological field mapping and observations; refraction seismic surveys; review of site-specific subsurface geological and geotechnical data, including borehole logs and samples from boreholes, test pits, and trenches; aerial reconnaissance and analysis of stereo-pair aerial photographs; geologic interpretation of existing LANDSAT satellite imagery; and studies of previous work. Details of the data gathering and interpretation procedures are provided in the documents referenced in this section.

2.2 REGIONAL GEOLOGY

As noted in the NRC SRP, regional geology must be defined in sufficient detail to provide a clear perspective and orientation to site-specific subsurface information.

The DOE has characterized the regional geologic conditions in the site geology report (Attachment 2). Information in this RAS report was derived from published studies referenced in Attachment 2. The site region is defined as the area within a 40-mi (65-km) radius of the disposal site.

2.2.1 Regional physiography

As required in the NRC SF&C guide, the following main physiographic features of the region will be characterized:

- Type of geomorphic surface that surrounds the site.
- General relief and topography of the region.
- Regional drainage systems.
- Major regional geomorphic processes.

The Burro Canyon site is in the northeastern part of the Colorado Plateau physiographic province near its boundary with the southern Rocky Mountain province. This portion of the Colorado Plateau is characterized by large-scale folds, unwarped plateaus, and deep, narrow river canyons. The entrenched meanders of the Dolores River and the folded belt of the Paradox Basin are the principal features of the region.

Further details of the regional physiographic setting and the basis for the above description are contained in Section 2.1 of Attachment 2. That section describes the geomorphic landforms, the relief and topography of the region, the drainage systems, and the types and rates of the major geomorphic processes.

2.2.2 Stratigraphic setting

Bedrock in the site region includes exposures of complete stratigraphic sequences of Mesozoic deposits. Most upper Cretaceous and all Tertiary deposits have been removed by erosion. Paleozoic rocks underlie the region but are rarely exposed.

Further details of the technical approach to and the results of the characterization of the regional and site stratigraphy are in Section 2.2 of Attachment 2. Figures 2.3, 3.1, and 3.2 of Attachment 2 show the bedrock within the site region and site area. Table 2.1 of Attachment 2 describes the stratigraphic units. This document further details the age, name, thickness, lithology, induration, relation to adjacent units, and geographic distribution.

2.2.3 Structural setting

The site is located in the Colorado Plateau structural province, which is an intercontinental subplate with a thicker crust than adjoining provinces. Substructures within the plateau consist of broad basins containing thick Tertiary deposits and uplift structures with exposures of Precambrian basement rock.

Details of the site structural setting are described in Section 2.3 of Attachment 2. The regional structural elements (Figures 2.4 and 2.5 of Attachment 2) show the relationship of the site region to adjoining structural provinces.

The bedrock structure of the disposal site foundation is described in Section 3.1 of Attachment 2 and is illustrated on the geology map in Figure 3.1 of Attachment 2.

2.2.4 Seismotectonics

The DOE has characterized the potential for tectonic activity in local and regional structures that may contribute to earthquake generation and may affect the suitability of the site and design as follows.

Seismicity

The seismotectonic characteristics of the Colorado Plateau and adjacent provinces are given in Table 2.2 of Attachment 2. The maximum earthquake (ME) of the source area and the resultant acceleration at the site are shown in Table 2.5 of Attachment 2.

The historical seismicity of the region of all earthquakes of magnitude 4.0 or greater within a 40-mi (64-km) radius of the site is presented in Table 2.4 of Attachment 2. This historical record is derived from the seismic data for a radius of 125 mi (201 km) from the site including the date, location coordinates, depth of focus, intensity, and magnitude. The original 1985 earthquake data file for this site has been updated by reference to the 1989 data file of the nearby Dry Flats site near Naturita, Colorado (NGDC, 1989). Because the largest earthquake predicted or experienced within the western United States is a magnitude 8.2 event, the accepted attenuation/distance relationship for this event at a distance of 40 mi (64 km) is not expected to result in a peak horizontal acceleration (PHA) at the site that would exceed the PHA for a 6.2 magnitude event as a floating earthquake (FE) located 9.3 mi (15 km) away. The 40-mi (64-km) site radius is therefore considered appropriate for design purposes.

The seismic record is discussed in detail in Section 2.4 of Attachment 2. It describes seismic activity that is related to remote seismic source zones. A brief summary of the main points follows.

Seismicity for the site region, based upon credible locations of historical earthquakes and instrumentally located epicenters, has occurred mostly in the border zones of the Colorado Plateau and in the intermountain seismic zone. The largest events recorded within the Colorado Plateau are in the range of 5.3 to 5.7 magnitude. The largest earthquake within a 125-mi (201-km) radius was of 5.5 magnitude located 130 mi (209 km) southeast of the site in the Rio Grande Rift area near the New Mexico-Colorado border. Only one macroseismic earthquake occurred within the site region, with a magnitude 4.0 event in 1970 at a distance of 33 mi (53 km).

The following information is the basis of the parameters used in designing the disposal cell to ensure stability against earthquake-induced instability (see Section 4.2 of Attachment 2).

Tectonics

Section 2.4 of Attachment 2 details the seismotectonic setting related to the structural geology of the region. The tectonic provinces are defined in Figure 2.4 of Attachment 2. These provinces are based on previously referenced studies of the region that present the correlation of structural features with seismic activity. Evidence of tectonic activity with the Colorado Plateau province and adjacent provinces (such as uplift or subsidence rates, evidence of active fault traces, and volcanism) are cited as characteristics of each province. Plate 2.1 of Attachment 2 shows the epicentral locations within a 40-mi (64-km) site radius relative to the known fault systems within the site region. Important aspects of the regional tectonics are summarized below.

The interior portion of the Colorado Plateau province in which the disposal site is located is considered stable, with a more active border zone on its east, west, and south sides. Neogene faulting is rare within the interior. An exception is the Uncompahgre Uplift structure where minor earthquakes have been associated with faults on its northeastern side and its southeastern terminus with the western mountains. These faults are located beyond the site region.

This information on the site region tectonics is the basis of the estimation of site-specific seismic design parameters.

2.2.5 Resource development

To ensure that future resource development will not jeopardize the remedial action, the occurrence of recoverable resources in the site area must be characterized. Resources of concern are those which, if exploited, could result in inadvertent intrusion into the disposal site.

Economic resources in the site region consist essentially of uranium and vanadium ore located within the Salt Wash Member of the Morrison Formation. The nearest mine is approximately 0.5 mi (0.8 km) southwest of the site in the Slick Rock uranium mining district.

The DOE has identified the resources occurring nearest the site, such as uranium ore and gas and oil deposits. Suspected uranium and vanadium ore zones 1 or 2 ft (0.3 to 0.6 m) thick occur at depths of 900 ft (274 m) below the site. These ore deposits are not considered economically important resources at the present time because of the depressed uranium market. Based on the calculation for the impact of mining at that depth (presented in the Appendix to Attachment 2), resource future development will not affect or be affected by the proposed remedial action.

Further details of the resources of the site and region are presented in Section 2.5 of Attachment 2. The locations of mineral resources are shown in Figures 2.9 and 2.10 of Attachment 2.

2.3 SITE GEOLOGY

Bedrock geological conditions at the site are characterized primarily to provide the basic information required for site geotechnical stability evaluations and groundwater performance assessments. Surficial geologic conditions are characterized to establish the geomorphic history and processes at the site, and hence to determine that long-term stability standards will be met.

The procedures used to characterize site geology and the details of that site characterization are contained in Section 3.0 of Attachment 2. Figures 3.1 through 3.7 of Attachment 2 characterize the site geology and geomorphology through topographic base maps and cross sections. Salient site geologic features are described below.

2.3.1 Bedrock geology

The bedrock that underlies the site consists of shales and thin sandstones of the lower unit of the Dakota Sandstone Formation, which is underlain by the mudstone/claystone of the Burro Canyon Formation. The most significant strata in terms of hydrogeology are an upper sandstone at a depth of about 80 ft (24 m), a middle sandstone at a depth of about 170 ft (52 m), and a lower sandstone at a depth of about 300 ft (90 m).

The cell will be founded in the mostly carbonaceous shale and in the sandstone strata of the Dakota Sandstone Formation.

2.3.2 Surficial geology

Surficial deposits on the approximately 18-ac (7.3-ha) mesa surface consist of thin soil covering the interior drainage basin of the site. Thickness ranges from less than 1 ft (0.3 m) at the perimeter to 4 ft (1.2 m) along the interior drainage swale. Because most of the surface area will be utilized in the cell design, the soil will be stripped to bedrock and stockpiled for other use.

The surficial soils on and around the site are shown in Figure 3.7 of Attachment 2 and are discussed in Section 3.2 of Attachment 2.

The DOE concludes that the surficial deposits will not detrimentally affect the long-term stability of the disposal cell.

2.3.3 Geomorphology

Site geomorphology is characterized to confirm the stability of the current landscape and to provide reasonable assurance that stability will be maintained for the performance period required by the standards. The DOE has characterized the regional and site geomorphology by referring to published literature, topographic maps, site inspections, and the procedures described in the TAD. Details of the regional geomorphology are provided in Section 2.1 of Attachment 2. Site-specific geomorphology is described in detail in Section 3.3 of Attachment 2. The main aspects of the geomorphology directly relevant to site remedial action are summarized below.

The site lies on a small mesa protected by outcrops of the resistant sandstone strata in the lower Dakota Sandstone Formation. The rim of the mesa forms the drainage divide so that no off-site overland flow can occur. Drainage on the mesa is interior with only a single outlet founded on sandstone that occurs at the south rim. The principal geomorphic process at the site is scarp retreat and head cutting. All tributary drainage around the mesa terminates on the exposed rock rim of the mesa. Natural armoring of the mesa slopes has developed from the detritus of the sandstone ledges.

The DOE has examined the geomorphic processes that could affect site stability and has described the geomorphic processes that created the landforms and the geomorphic processes that are likely to take place in the future (see Sections 2.1 and 3.3 of Attachment 2). This characterization is considered sufficient to undertake an assessment of the geomorphic stability of the site, as described in Section 2.4.1 of this report (where the DOE confirms that there is a reasonable assurance that stability will be maintained for the performance period of the design standards).

2.4 GEOLOGIC STABILITY

This section describes the local geologic and seismic conditions likely to affect the geotechnical stability of the disposal cell and the long-term stability of the landscape environment. It also analyses the characteristics of unconsolidated deposits and geomorphic processes at the site that may affect long-term stability. In general, this section characterizes the suitability of the site geology including lithology, stratigraphy, and structural conditions as a foundation for the disposal cell.

2.4.1 Geomorphic stability

The DOE provides evidence of the long-term stability of the site in Section 3.0 and describes the stability that is expected for the performance period of the proposed remedial action in Section 2.1 of Attachment 2. The main aspects of the geomorphic stability of the site are discussed below.

The site has experienced long-term geomorphic stability. The topography indicates that stable conditions are likely to continue for the performance period of the remedial action. The evidence for geomorphic stability is shown by the resistance of the cap rock sandstone to development of gullies on the mesa sideslopes and in the exit drainage of the mesa top.

To enhance geomorphic stability, a minimum setback of 100 ft (33 m) from the edge of the mesa escarpment is recommended for the contaminated materials. Where the integrity of the mesa rim is encroached, the sideslopes will require placement of erosion protection rock. The central drainage exit at the south side of the mesa, if overlapped by the cell, will require erosion protection against headward advance of this tributary.

The age of the geomorphic surfaces has been established in the preceding sections by reference to the rate of the scarp retreat. The geomorphic processes that could influence the disposal cell and remedial action have been identified and quantified by the DOE. Specific projections relating to recommendations and engineering designs for site stability are presented regarding the potential for scarp retreat and headward advance of the tributaries. On the basis of these evaluations, the DOE concludes that the site is geomorphically stable and will continue to be for the performance period of the disposal cell.

2.4.2 Seismotectonic stability

The DOE has determined that the disposal site and designs will provide long-term stability during seismic events by developing an understanding of the anticipated ground motion at the site as a result of these events. Having catalogued the seismic activity, identified the significant geologic structures, and delineated the tectonic provinces, the DOE provides an analysis of the seismic sources that would most affect the stability of the site in Section 2.4 of Attachment 2. Each potentially active fault and the remote seismotectonic sources are shown in Tables 4.1 and 4.2 of Attachment 2 and discussed in the text, with the calculated ME and the estimated ME of previous studies. Using appropriate attenuation relationships for the site region, the PHA for these sources and a FE is also presented. Only one fault system has been identified as having a critical potential acceleration relative to the FE as a design event. This fault system is determined to be noncapable so that the FE is determined to be the design earthquake.

The design earthquake for this site was determined to be an $M_L = 6.2$ event occurring at a distance of 9.3 mi (15 km) from the site as an FE. The PHA of bedrock at the site is estimated to be 0.21 gravity (g). Details of the studies leading to this conclusion are given in Section 4.2 of Attachment 2.

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 groundwater information to assess slope stability. The geotechnical engineering aspects of the remedial action at the Slick Rock, Colorado, sites are presented in Section 3.0 of this document and in applicable calculation sets of Attachment 1.

Seismic design parameters were derived using procedures that are presented in Section 1.2 of Attachment 2. These procedures are set forth in the TAD (DOE, 1989a). The acceleration attenuation relationship of Campbell (1981) was used to derive the on-site peak horizontal acceleration.

Design criteria

- Long-term slope stability seismic coefficient: $K = 0.14$ (0.66 of PHA).
- Short-term slope stability seismic coefficient: $K = 0.10$ (0.5 of PHA).
- Liquefaction analysis: ground surface horizontal acceleration $a_{max} = 0.21$ g.

Potential geologic conditions, including seismic shaking, liquefaction, on-site rupture, ground collapse, and volcanism, are ruled out as potential disturbing forces on the disposal cell, either because they will not occur or because the geotechnical design of the cell is formulated to resist such forces.

2.5 GEOLOGIC SUITABILITY

On the basis of the site characterization described in this section and supporting documents, the details of the final RAP, and the provisions for stability included in the design of the disposal cell, the DOE concludes that there is reasonable assurance that regional and site geologic conditions have been characterized adequately to meet the requirements of 40 CFR 192. Conditions potentially affecting long-term stability have been identified and either avoided by design layout or mitigated by the details of the remedial action design.

3.0 GEOTECHNICAL STABILITY

3.1 INTRODUCTION

This section and supporting references describe the geotechnical engineering aspects of the remedial action at the Slick Rock, Colorado, sites. The following aspects of the remedial action are described: geotechnical information related to the processing, borrow, and disposal sites; design details related to the disposal site and the disposal cell and its cover; and materials associated with the remedial action, including the foundation and excavation materials, tailings, and other contaminated materials. Related geologic aspects, such as site geology, geomorphology, and geomorphic and seismic characterization, are presented in Section 2.0. Surface water and erosion control are described in Section 4.0. Groundwater conditions at the sites are described in Section 5.0.

3.2 SITE AND MATERIAL CHARACTERIZATION

3.2.1 Geotechnical investigation

Geotechnical investigations and site characterization programs were performed at both processing sites and at the disposal and borrow sites. The data obtained during these site characterization programs are presented in the Attachment 1, Information for Bidders, Volumes I, II, III, and IV (May 1993). The geotechnical investigations included excavating test pits and augering boreholes. See Attachment I, Drawing Nos. SRK-GE-10-0304 and SRK-PS-10-0318, SRK-PS-10-0325, and SRK-DS-10-0338, for the location of test pits and boreholes. Test pit and borehole logs are compiled and included in Attachment 1, Information for Bidders, Volumes III and IV, and Appendix B of Attachment 3.

Processing sites

Tailings materials at the Slick Rock processing sites are located at the UC tailings pile and the NC tailings pile. Two site characterization programs were conducted at the processing site. The pre-1987 program conducted by the TAC included 3 test pits at the NC pile and 19 test pits excavated at the UC pile. DOE conducted additional subsurface investigations at the UC pile by augering 51 boreholes and performing 12 piezocone soundings. Another 26 boreholes were advanced at the NC site. Bulk samples were taken for laboratory analyses that required larger amounts of material.

Additional data were collected at the Slick Rock processing sites during investigations performed in 1987 and 1989. The TAC drilled another 13 boreholes at the UC site in 1989. The Remedial Action Contractor (RAC) also collected and analyzed soil samples from an additional 20 boreholes and 21 test pits at the UC site and 2 boreholes and 12 test pits at the NC site. All

applicable logs from the processing site can be found in Attachment 1, Information for Bidders, Volume III, and Appendix B of Attachment 3.

Disposal site

The DOE performed the disposal area subsurface investigations, obtaining geotechnical data from 20 test pits excavated with a backhoe. The test pits were advanced to depths of 3 to 10 ft (1 to 3 m). Additional geotechnical data were obtained from 16 well boreholes and 6 coreholes advanced during 1990. The coreholes were drilled to depths ranging from 80 to 430 ft (25 to 130 m). Disturbed and undisturbed samples were obtained from the boreholes using standard sampling and penetration techniques. Only disturbed samples of material were obtained from test pits. Test pit and borehole logs are compiled and presented in Attachment 1, Information for Bidders, Volume III, and Appendix B of Attachment 3.

Borrow areas

The DOE conducted numerous investigations of borrow areas. A total of 27 test pits (9 by the TAC and 18 by the RAC) were excavated and logged to characterize the soil at the Disappointment Valley borrow site. Soil from the Disappointment Valley borrow site will be used to construct the radon barrier. All test pits were excavated using a backhoe. Bulk samples were collected for laboratory determination of moisture content and the geotechnical characteristics of remolded samples. Samples of the erosion protection rock, ranging from gravel to cobble-sized material, were obtained from 23 test pits excavated in the Dolores River borrow sites located between the UC and NC piles. Two of the 23 test pits are located at the Troy Rose gravel pit. An additional rock borrow source is located about 0.2 mi (0.4 km) south of the mill site on the western bank of the Dolores River. Rock samples from this site were obtained from three deep test pits and three boreholes. Test pit logs are compiled and presented in Attachment 1, Information for Bidders, Volume IV, and Appendix B of Attachment 3.

3.2.2 Testing program

The materials at the Slick Rock processing sites were classified and tested. The testing program included sieve analysis (gradation), Atterberg limits, specific gravity, moisture density determinations, compaction and consolidation tests, determination of saturated hydraulic conductivity, percolation and water pressure tests, capillary moisture analysis, direct shear tests, and triaxial shear strength tests. The results of the individual tests are presented in Attachment 1, Information for Bidders, Volume IV. Summary tables and selected geotechnical design parameters are found in Attachment 1, Volume I, Calculation No. SRK-250-04-03.

Disposal site foundation and borrow materials

The DOE conducted the geotechnical engineering testing program for the Burro Canyon disposal site, Disappointment Valley radon barrier borrow site, and Dolores River Canyon rock borrow sites. The test program for characterizing the disposal site foundation soils included performing field moisture and density tests in five test pits using the sand-cone method. Soil from depths of from 3 to 10 ft (1 to 3 m) below the surface were tested. Additional data on the disposal site foundation were obtained from laboratory testing of borehole samples taken from depth ranging from 20 to 90 ft (6 to 27 m) below the ground surface. The Disappointment Valley borrow site test program included soil classification and material properties testing. Testing included gradation, Atterberg limits, consolidation tests, saturated hydraulic conductivity, organic content, capillary moisture, triaxial shear strength, and moisture-density relationships. Rock durability tests and petrographic analyses were performed on rock from the Dolores River borrow sites. The durability tests performed were the Los Angeles Abrasion, sulfate soundness, sodium adsorption and specific gravity, and Brazilian tensile strength tests. Petrographic analyses were performed as described by the American Society for Testing and Materials (ASTM) (ASTM, 1987). The results of the individual tests are contained in Attachment 1, Information for Bidders, Volumes III and IV.

Conclusion

All laboratory and field testing procedures followed the standards published by the ASTM or the U.S. Army Corps of Engineers, Engineering Manual EM 1110-2-1906 (COE, 1970a). The testing program employed a sufficient number of samples and tests to define all critical soil parameters appropriate for support of the engineering analyses. In addition, the scope of the testing program and the use of resulting data to define material properties are in general conformance with the applicable provisions of the NRC SRP (NRC, 1985). Quality assurance (QA) and quality control (QC) activities followed appropriate UMTRA Project procedures.

3.2.3 Groundwater conditions

Processing sites and rock borrow sites

Three groundwater systems are present in the vicinity of the UC and NC sites and the proposed rock borrow sites: 1) the unconfined Dolores River alluvium, 2) the semiconfined to confined Entrada Formation, and 3) the unconfined to semiconfined Navajo Sandstone. These three hydrostratigraphic units are interconnected in the vicinity of the processing sites. Additional information is provided in Section 5.1 of this document.

Disposal site

Four hydrostratigraphic units consisting of one unsaturated unit and three saturated units underlie the proposed disposal site. The unsaturated hydrostratigraphic unit is the lowest unit of the Dakota Sandstone and the uppermost Burro Canyon Formation claystones and mudstones. The three saturated sandstone units are within the Burro Canyon Formation at approximate depths of 100, 200, and 300 ft (30, 60, and 90 m) and are described as the upper, middle, and lower sandstone units, respectively. The upper sandstone unit of the Burro Canyon Formation is the uppermost aquifer underlying the disposal cell footprint. This unit is characterized by low yield and limited use. Groundwater movement in the upper sandstone unit is semiconfined. Groundwater in lithologic units underlying the upper sandstone unit is protected from potential site-related contamination by 1) hydrogeologic isolation provided by the low permeability mudstone units that inhibit the downward migration of water, and 2) upward vertical hydraulic gradients in the confined lower and middle sandstone units of the Burro Canyon Formation.

3.2.4 Site stratigraphy

Processing site

The UC site lies on a bench of Entrada Formation Sandstone with a thin, probably discontinuous Quaternary terrace gravel cover and overlaps the bedrock bench toward the river onto a thicker, younger gravel deposit. The NC site lies partially on sandstone and mudstone of the Salt Wash Member of the Morrison Formation and partially on Quaternary terrace gravels.

At Slick Rock, the slimes were removed for processing at Rifle, Colorado, leaving only sand tailings. Tailings in the UC pile generally contain less than 15 percent fines, while samples of NC tailings contain generally less than 5 percent fines.

Disposal site

The soil at the Burro Canyon disposal site consists of reddish-brown, sandy clay to clayey sand with thicknesses ranging from 0 to 1.5 ft (0 to 0.5 m) at the perimeter of the mesa top to 0.25 to 4.5 ft (1.0 to 1.4 m) in the middle of the site. In most places, the soil is directly underlain by a thin sandstone stratum. In a few locations, the soil covers a dark-gray, carbonaceous shale/claystone. The lowest unit of the Dakota Sandstone Formation forms the foundation at the site. A more detailed discussion of the stratigraphy and geology of the disposal site is presented in Section 2.0 and Attachment 2.

Borrow sites

The Disappointment Valley radon barrier borrow site is overlain by approximately 1 ft (0.3 m) of a brown, silty clay topsoil. Underlying this surface layer, a silty-clayey sand layer ranging from 0.7 to 4.5 ft (0.2 to 1.4 m) in thickness was

encountered. A medium plastic Mancos Shale layer lies beneath the clayey sand layer. The clayey sand and weathered sections of the Mancos Shale are suitable for radon barrier material.

The proposed borrow sites for riprap and gravel are adjacent to the Dolores River. The stratigraphy of the sites is generally a sand overlying a moderately thick river terrace deposit. The terrace deposits contain subrounded, gravel-size particles and subrounded cobbles ranging in size from 6 to 8 in (15 to 20 cm) in diameter. Based on the site characterization data, and flood and floodplain analyses, the terrace deposits should contain a sufficient quantity of large diameter rock to construct the erosion protection features of the Burro Canyon disposal cell.

3.3 GEOTECHNICAL ENGINEERING EVALUATION

3.3.1 Introduction

This section and the supporting documents referenced in Table 1.2 present the engineering evaluation of the information and analyses that were undertaken to demonstrate that the proposed remedial action design will meet the EPA standards for long-term stability, including slope stability, settlement, liquefaction, and cover cracking. The analyses were performed for design-basis events such as the design earthquake, the design flood, and extreme meteorological conditions.

3.3.2 Slope stability

The geotechnical stability of the disposal embankment slopes was evaluated. The most critical slope sections were analyzed for both the short-term, end-of-construction state, and long-term state. Excavation slopes were evaluated to ensure stability during construction. A brief description follows of the work that supports these conclusions.

Disposal cell slopes

A plan of the pile layout and the location of the most critical sections are presented in Attachment 1, Calculation 11-320-01-00. Soil parameters for the compacted tailings and radon barrier were established by appropriate testing of representative material. Values of soil parameters for the select fill, riprap, and foundation materials were assigned, based on published data and data obtained from the geotechnical explorations at the site. Soil parameters used for the evaluation are presented in Attachment 1, Calculation 11-250-04-03.

The Modified Janbu Method and infinite slope methods were employed to assess the conditions to which the critical slope might be subjected. Results are shown in Table 3.1. Factors of safety against failure were analyzed for both static and seismic loading conditions. The seismic stability of the slope was investigated by the pseudostatic method of analysis using horizontal seismic coefficients of 0.14 for the short-term case and 0.18 for the long-term case. Pseudostatic methods are considered acceptable because of the conservatism

Table 3.1 Results of slope stability analysis*

Case	Loading condition	Short-term conditions (EOC)	Long-term conditions (LT)
Section A-A' (excavation)	Static	1.31 ^b 1.34 ^c	NA
Section B-B' (excavation)	Static	1.27 ^b 1.36 ^c	NA
Section C-C' (embankment)	Static	3.03	3.00
	Seismic	2.02	1.84
Infinite slope (shallow plane)	Static	2.67	6.32
	Seismic	1.85	4.00

*As specified by the TAD (DOE, 1989a).

^bBlock failure.

^cCircle failure.

NA - Not applicable.

employed in determining soil parameters and seismic coefficient values. Minimum requirements for the static loading conditions and seismic loading conditions are specified in the TAD (DOE, 1989a).

Excavation slopes

The excavation slopes will be 2.5 horizontal to one vertical (2.5:1) along the disposal cell perimeter. Soil parameters for the disposal area foundation material were assigned on the basis of data obtained from geotechnical explorations and published data; they are presented in Attachment 1, Calculation 11-250-04-03. The Modified Janbu Method was used to determine the excavation slope stability during construction for static loading conditions. A minimum factor of safety against failure of 1.27 was determined for slope section B-B'. The TAD specifies a minimum of 1.3 for stability during construction. Because the Janbu Method always yields a factor of safety 0.1 to 0.2 less than required, the previous results are acceptable.

Conclusion

The methods of analysis employed are considered to be conservative approaches and satisfy the requirements in the TAD. In addition, the most critical conditions to which the slopes might be subjected have been considered and the characteristics of all slopes have been well defined. From the results of the slope stability evaluation it can be concluded that the embankment slopes would be stable under short-term and long-term conditions, and thus would comply with the EPA standard 40 CFR Part 192.02(a) for long-term stability.

3.3.3 Settlement

As a result of volume changes in the tailings and foundation materials, differential settlement of the disposal cell was evaluated to determine the potential for disruptive conditions such as surface water flow concentration, ponding, or cracking of the radon barrier cover. The locations evaluated were chosen to determine the range of total and differential settlements across the cell. A detailed analysis of settlement is presented in Attachment 1, Calculation 11-323-01-00.

Soil parameters for the radon barrier and compacted tailings were determined from appropriate testing of representative material. The other materials, including the select fill and foundation, were assigned soil parameter values on the basis of data obtained from geotechnical investigations and published data.

Multilayered analyses using conventional consolidation theory were used to evaluate the amount of primary and secondary settlement and the time rates of primary settlement that will occur at locations on both sides of this interface. Comparison was made of the secondary consolidation at different locations to determine long-term differential settlement gradients across the interface. Results of this analysis (see Attachment 1, Calculation 11-323-01-00), show that the cover will not experience significant cracking, nor will water collect on the top of the embankment.

3.3.4 Liquefaction potential

For liquefaction to occur, a soil must be saturated, loose, and cohesionless. Both the compacted tailings and foundation material satisfy the cohesionless criterion, but because of an infiltration inhibiting radon/infiltration barrier and a depth of 80 to 150 ft (27 to 50 m) to groundwater, the tailings and foundation material will not become saturated. In addition, neither the compacted tailings nor the medium dense-to-dense foundation material can be considered loose. Therefore, the stabilized tailings embankment is not susceptible to liquefaction.

3.3.5 Cover design

Figure 1.6 shows a cross section of the cover system. A more detailed schematic of the cover system is shown in Attachment 1, Drawings SRK DS-10-0335 and SRK-DS-10-0336. The design for the disposal embankment cover consists of the following layers, descending from the top: an 8-in (20-cm)-thick layer of riprap, a 6-in (15-cm)-thick sand/gravel layer, a 2.0-ft (0.6-m)-thick frost protection layer, and a 2.0-ft (0.6-m)-thick radon barrier. The only difference between the top and sideslope covers is that the riprap layer on the sideslope will be 1.0 ft (0.3 m) thick. Cover component material types and functions are listed in Table 3.2.

Table 3.2 Cover components and their function

Cover component	Material type	Function
Erosion protection layer	Riprap	- Prevents erosion of the disposal cell by surface water runoff.
Bedding layer	Sand/gravel	- Bedding layer—prevents displacement of large-diameter rock. - Protects frost protection layer (fine-grained material) from erosion. - Drains water laterally.
Frost protection layer	Fine-grained soil with some sand	- Protects the radon/infiltration barrier from the effects of frost.
Radon barrier	Sandy clay	- Inhibits radon emanation. - Inhibits infiltration through the underlying contaminated material.

Conclusion

The material properties and available quantities for the cover materials have been adequately defined in a manner that conforms with the applicable provisions of the SRP. In addition, the performance of the cover system has been evaluated using both state-of-the-art techniques and standard engineering methods; the result is that the cover will remain effective for a period of time that is in compliance with the EPA standard 40 CFR Part 192.02 for long-term performance.

3.3.6 Subsidence

Because mining may take place beneath the Burro Canyon site in the future, the potential exists for subsidence of the foundation soil of the disposal cell footprint. The potential effect of subsidence on the stability of the disposal cell was assessed in the Appendix to Attachment 2, TAC Calculation SRK-04-90-03-03-00. Based on previous mining practices in the area and conservative assumptions for analysis, future uranium and vanadium mining of the Upper Salt Wash Formation will not adversely affect the long-term stability of the disposal cell at Burro Canyon. The top of the Upper Salt Wash Formation is approximately 900 ft below the surface of the proposed Burro Canyon disposal site.

3.4 CONSTRUCTION DETAILS

3.4.1 Construction methods and features

Detailed descriptions of the remedial action are provided in Attachment 1, including site plans and engineering drawings that convey the remedial action design features and construction specifications that provide a detailed explanation of the proposed construction methods. In addition, Attachment 1, Calculations, Volumes I through VI, contains calculations that support the remedial action design features and volumes of materials.

Remedial action will meet the following general construction requirements:

- The maximum percentage of organics contained within the reshaped disposal cell should not exceed 5 percent by volume, and the material should be distributed so as to avoid pockets or layers of organic matter.
- All uncontaminated vegetation and organic material in areas subject to excavation and placement should be removed and disposed of off the site.
- Contaminated demolition debris should be reduced to manageable pieces and carefully placed in the embankment to ensure that no voids or nesting exist around the debris and that the adjacent contaminated materials are compacted to 90 percent of the Standard Proctor (ASTM D698) (ASTM, 1987).
- Excavation of all contaminated materials should be monitored carefully to prevent the inclusion of unnecessary, uncontaminated material in the pile.
- The surfaces of all areas where fill materials will be placed should be proof-rolled before placement of contaminated materials. Soft zones should be excavated and replaced with compacted material.
- The relocated tailings and contaminated materials should be compacted to at least 90 percent of the Standard Proctor density (ASTM D698) (ASTM, 1987) and should be moisture-conditioned or dried to specified moisture content to achieve specified density.
- Design criteria for the radon barrier cover include 1) placement at a minimum of 95 percent of the Standard Proctor density (ASTM D698) (ASTM, 1987), 2) at or near the optimum moisture content, and 3) compaction by a kneading method.

3.4.2 Testing and inspection

Attachment 1, Subcontract Documents, details the methods, procedures, and frequencies by which construction materials and activities will be tested and inspected to verify compliance with the design specifications.

Quality will be controlled in accordance with the DOE/UMTRA quality assurance plan (DOE, 1990). The DOE and the TAC will conduct QA audits and an in-process surveillance to verify and ensure that remedial action activities are performed in accordance with approved UMTRA Project requirements.

3.4.3 Construction activities and construction sequence

General

Construction activities will take place at the existing tailings sites (UC and NC sites), areas contaminated by windblown and waterborne tailings at the proposed Burro Canyon disposal site, and at borrow sites.

During remedial action construction, all contaminated runoff will be contained. Contaminated disturbed areas at the UC site will be graded so that runoff flows to a retention basin. Uncontaminated disturbed areas will be graded to divert runoff from contaminated areas.

Ditches at both the UC and NC sites and the Burro Canyon disposal site will be sized to carry the peak runoff flows from a 10-yr, 1-hour (hr) storm event and will serve to prevent uncontaminated runoff from impinging on contaminated areas.

The retention basin will receive water from contaminated areas and decontamination activities, including equipment and truck washdowns. The retention basins at the processing site and the disposal site are designed to retain the maximum runoff for a 1-month period, as well as wastewater generated from the remedial action activities and all sediment inflow during the remedial action.

The emergency spillway from the basin is designed to discharge the 25-yr, 1-hr storm runoff while 1 ft (0.3 m) of freeboard is maintained between the top of the embankment and the water surface.

Wastewater treatment

Wastewater will be directed to the retention basin to provide primary settling as well as flow and contaminant equalization. The treated water from the basin will be used for dust control and vehicle decontamination.

Equipment decontamination pad

To prevent contaminated materials from being carried out of the construction areas, decontamination pads with a holding pond and a pump will be provided at the UC and NC sites and the Burro Canyon disposal site to wash contaminated equipment.

Dust control

Dust generated by excavating, earth moving, vehicle use, temporary material stockpiling, and other activities will be controlled and minimized by the use of water and water-based surfactants.

Water recycled from the wastewater retention ponds will be used to suppress dust created by stockpiling and working with contaminated materials.

Construction sequence

The following construction sequence is proposed for the remedial action. The final schedule will contain more details and the construction subcontractor will be allowed flexibility in the final construction sequence. Activities are presented in the order in which they should occur, although some events will be concurrent.

1. Excavate in UC tailings embankment area for road detour and gas pipeline relocation.
2. Construct detour for County Road CR-S8. Upgrade unimproved haul road starting at Colorado State Highway 141 and ending at the Burro Canyon disposal site.
3. Relocate utilities, firehouse, and housing trailers.
4. Erect perimeter fences around UC and NC sites and remove existing fences.
5. Seal existing monitor wells.
6. Excavate and stockpile contaminated materials from UC and NC access control and decontamination pad areas. Construct access control areas and decontamination pads.
7. Demolish abandoned structures and utilities encountered and stockpile the debris.
8. Construct retention basins including dikes, spillways, and temporary drainage ditches. Stockpile contaminated material excavated in this process for later disposal in the tailings embankment; stockpile uncontaminated materials excavated for later use as fills. Begin grading required for site drainage.
9. Open borrow sites.
10. Excavate tailings embankment foundation at the Burro Canyon disposal site.
11. Construct decontamination pad and access control area at the disposal site.

12. Excavate and transport NC-contaminated materials to the disposal cell.
13. Complete site grading of the NC area.
14. Excavate and transport UC-contaminated materials to the disposal cell.
15. Demolish decontamination facilities, including decontamination pad and recirculation pump, and dispose of debris in the tailings embankment.
16. Dispose of contaminated sediments and geomembranes from the temporary drainage ditches and the retention basins at the UC site in the disposal cell.
17. Place radon barrier over contaminated material.
18. Place erosion protection material, including the frost protection layer, over the radon barrier.
19. Site cleanup: Remove and dispose of subcontractor's stockpiled material, close the borrow areas, and remove site perimeter fencing.
20. Site restoration: Grade the UC area, the borrow areas, and the stockpile areas to provide drainage; place and grade uncontaminated fill; and seed.

Schedule

Remedial action is scheduled to commence in April 1994. Winter shut-down periods may be up to 5 months. The construction schedule may be refined during the final design process.

3.5 SUMMARY

Geotechnical engineering and construction evaluations were conducted using common engineering practices and commonly accepted techniques. These evaluations extended to levels of detail that are in general conformance with applicable provisions of the NRC SRP for UMTRA Project Title I mill tailings RAPs. Evaluation of the previous results show that the proposed remedial action design will comply with the EPA Standard 40 CFR Part 192, Subpart A, for geotechnical engineering and construction.

4.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

4.1 HYDROLOGIC DESCRIPTION AND REMEDIAL ACTION DESIGN

The average elevation of the Burro Canyon disposal site is 5875 ft (1791 m) above MSL. The disposal site is located on a small mesa that is completely isolated from runoff from upland drainages. The drainage north and east of the site is the Nicholas Wash Basin. The disposal site and basins south of the site drain into Joe Davis Canyon. Runoff in the two shallow drainages located in the center of the site (mesa) drains by sheet flow until it reaches the south edge of the mesa; there the flow concentrates into a well-defined gully that incises the rim.

Flooding is not considered a hazard at the Burro Canyon disposal site because of its distance from and elevation above the closest stream channel. The drainage characteristics of the Burro Canyon disposal site are illustrated in Figure 4.1.

4.2 FLOODING DETERMINATIONS

To determine the impact of flooding to the sites, the DOE calculated peak flows and velocities, and evaluated the need for erosion protection features. All erosion protection features must withstand extreme meteorologic events such as the probable maximum precipitation (PMP).

4.2.1 Probable maximum precipitation

The determination of the site design PMP is presented in Attachment 1, Calculation No. 11-315-01-00. A local thunderstorm PMP of approximately 8.1 in (21 cm) in 1 hr is calculated for a small upland watershed (*i.e.*, the disposal site). The PMP rainfall estimate was developed using Hydrometeorological Report No. 49 (NOAA, 1977).

4.2.2 Infiltration losses

In computing the peak flow rate for the design of the rock erosion protection for the disposal cell top, sideslopes, and toe apron, the DOE assumed no infiltration would occur. This estimate is conservative with respect to erosion protection design (see Attachment 1, Calculations 11-322-01-00 and 11-322-02-00).

4.2.3 Time of concentration

For a given volume of runoff, the peak runoff for a given drainage basin (area) is inversely proportional to the time of concentration (T_c) for that basin. If the T_c is conservatively computed to be small, the peak discharge will be conservatively large.

LEGEND

- DRAINAGE DIVIDE**
- DRAINAGE**

**FIGURE 4.1
DRAINAGE SYSTEMS
BURRO CANYON SITE AREA,
SLICK ROCK, COLORADO**

The T_c for the topslopes and sideslopes was determined by dividing the slope lengths by the estimated flow velocities. The flow velocities were determined using the Manning Equation. For the design rock size and a critical path length of 120 ft (37 m), the T_c for the topslope is 2.5 minutes. The T_c for the sideslope is 3.0 minutes for a critical path length of 340 ft (104 m). The T_c are included in Attachment 1, Calculations SRK-322-01-00 and SRK-322-02-00.

4.2.4 Rainfall distributions - probable maximum precipitation

The DOE derived PMP rainfall depths and intensities from Hydrometeorological Report No. 49 (NOAA, 1977). The temporal distribution of the PMP depths and intensities was performed in accordance with the procedure described in the TAD (DOE, 1989a).

4.2.5 Computation of probable maximum flood

Adjacent waterways

The disposal site is located on a small mesa, and flooding of adjacent waterways will not impinge on the disposal cell. In addition, no upland drainages contribute runoff toward the site.

On-site drainage

Stephenson's Method (Stephenson, 1979) was used to determine the peak flow rates across the top and down the sideslopes of the disposal cell. Peak unit flow at the end of the topslope is 0.158 cubic feet per second per ft ($\text{ft}^3/\text{s}/\text{ft}$) [0.0147 cubic meters per second per meter ($\text{m}^3/\text{s}/\text{m}$)]. Peak unit flow for the sideslope is 0.391 $\text{ft}^3/\text{s}/\text{ft}$. The critical peak discharge across the toe apron is 0.39 $\text{ft}^3/\text{s}/\text{ft}$ and was determined using the Manning's Equation (see Attachment 1, Calculations 11-322-01-00 and 11-322-02-00).

4.3 FLOW DEPTH AND VELOCITIES

4.3.1 Adjacent waterways

Because the disposal cell is located on a small mesa that is much higher than the surrounding terrain, flooding in adjacent waterways will not impinge on the site. Therefore, analyses of adjacent waterways were not necessary.

4.3.2 Drainage ditches

Because of the disposal cell's location, no permanent drainage or interceptor ditches are required at the Burro Canyon disposal site. A naturally formed swale at the southern end of the mesa will be filled and graded (10 percent) to facilitate drainage from the top and sideslopes of the disposal cell.

4.3.3 Top and sides of the embankment

Manning's Equation was used to estimate a flow depth based on the peak sheet flow rate, slope, and an assumed Manning's n value. The appropriateness of the assumed Manning's n was then checked using the U.S. Army Corps of Engineers equation (COE, 1970b). Based on the calculated D_{50} rock size, the flow depth and velocity at the end of the topslope (for the maximum topslope of 2 percent) will be approximately 0.10 ft (4.2 cm) and 1.51 ft/s (0.46 m/s), respectively. For the 4:1 sideslopes, the calculated flow depth and velocity are 0.11 ft (3.4 cm) and 3.68 ft/s (1.12 m/s), respectively (see Attachment 1, Calculation 11-322-01-00).

The slope of the toe transitions from 25 percent on the sideslopes to a 2-percent apron slope. Based on the design D_{50} rock size, the flow depth and mean flow velocity over the toe apron will be 0.12 ft (3.8 cm) and 3.17 ft/s (0.97 m/s), respectively (see Attachment 1, Calculation 11-322-02-00).

4.4 EROSION PROTECTION

4.4.1 Topslopes

The surface layer of riprap on the topslope, which is designed to protect the disposal cell from wind and water erosion, has been sized to withstand the erosive velocities resulting from an on-pile PMP. The DOE proposes to use an 8-in (20-cm)-thick layer of rock with a required D_{50} of 1.7 in (4.3 cm). The riprap will be placed on a 6-in (0.15-m)-thick bedding layer. The safety factor method was used to determine the appropriate rock size for the topslope. A detailed discussion of rock sizing, including gradation information, is presented in Attachment 1, Calculations 11-322-01-00 and 11-322-03-00.

4.4.2 Sideslopes

The rock layer on the sideslopes, which also protects the disposal cell from wind and water erosion, is designed to withstand an occurrence of the local on-pile PMP. The DOE proposes to use a 1-ft (0.3-m)-thick layer of rock with a required D_{50} of approximately 4.0 in (10 cm). The D_{50} rock size where the sideslope transitions to the toe apron will be 5.8 in (15 cm). The rock layer will be placed on a 0.5-ft (0.15-m)-thick bedding layer. Stephenson's Method was used to determine the required rock sizes. Conservative values of 2.60 were used for the specific gravity of the rock, 38 degrees for the rock angle of internal friction, and 0.33 for porosity when solving Stephenson's Equation(s) (see Attachment 1, Calculation 11-322-01-00).

4.4.3 Toe and sides of the embankment

At the toe of the disposal cell, the DOE is placing a 5-ft (1.5-m)-thick layer of rock, with a minimum D_{50} rock size of 5.8 in (15 cm). Although several methods were used to estimate the rock size required for the toe apron, the

safety factors method (Stevens *et al.*, 1976) was selected as the best available method for the conditions at the toe of the disposal cell. Rock in the toe apron will be placed on a 1-ft (0.3-m)-thick sand/gravel bedding layer (see Attachment 1, 11-322-02-00). Erosion protection requirements are presented in Table 4.1.

Table 4.1 Rock size requirements and layer thickness for the Burro Canyon disposal cell

Location and grade	Rock size requirements			Layer thickness	
	Rock size	(in)	(cm)	(ft)	(m)
Topslopes (2%)	D ₅₀	1.7	4.3	8 in	0.2
Sideslopes (25%)	D ₅₀	4.0	10.2	1.0	0.3
Toe protection	D ₅₀	5.8	14.7	5.0	1.5

4.5 ROCK DURABILITY

The proposed rock borrow sites are located within 5 mi (8 km) of the proposed Burro Canyon disposal site. These sources are adjacent to the Dolores River and near the UC and NC sites. The gravel and riprap from the selected borrow sites were tested in accordance with the methods and tests described in NUREG/CR-2642 (Lindsey *et al.*, 1982). The average score of the tested material was 77. A total of 14 samples were tested and complete results of the tests are presented in Attachment 1, Calculation 11-231-02-02.

4.6 QUALITY CONTROL TESTING AND INSPECTION FOR EROSION PROTECTION

Attachment 1 provides details of testing and inspection procedures.

4.7 UPSTREAM DAM FAILURES

McPhee Dam is located approximately 36 mi (58 km) (linear distance) upstream from the Burro Canyon disposal site. Based on a flood and floodplain analysis of the Dolores River that included a dam-break scenario, a local PMP event by itself would cause much higher water levels in the Dolores River near Slick Rock than a catastrophic failure of the McPhee Dam and the subsequent release of impounded water. As the Burro Canyon disposal site is nearly 400 ft (122 m) higher than the invert elevation of the Dolores River, it will not be affected by the probable maximum flood or a breach of the McPhee Dam.

4.8 SUMMARY

The DOE concludes that the Burro Canyon disposal cell design will meet EPA requirements as stated in 40 CFR 192 with regard to flood design measures and erosion protection. An adequate hydraulic design has been provided to reasonably ensure stability of the contaminated material and tailings for a period of up to 1000 yr.

5.0 WATER RESOURCES PROTECTION

The DOE must demonstrate compliance with EPA standards for groundwater protection at inactive uranium mill tailings sites. These standards are contained in proposed revisions to Subparts A and C of 40 CFR 192 under Title I of the UMTRCA, as amended. Remedial action taken by the DOE must comply with the proposed standards until EPA promulgates them in final form (UMTRCA, Section 108) (PL 95-604). This section summarizes the water resources protection strategy for the Slick Rock uranium mill tailings Burro Canyon disposal site and demonstrates compliance with the proposed groundwater standards. Attachment 3 presents a detailed hydrogeologic characterization of groundwater at the UC and NC processing sites and the Burro Canyon disposal site. Attachment 4 presents the water resources protection strategy for the Burro Canyon disposal site.

To achieve compliance with the proposed EPA groundwater protection standards (Subpart A of 40 CFR 192), the DOE proposes to apply supplemental standards for Class III (limited use) groundwater because of low yield [less than 150 gallons per day (gpd) (7×10^{-3} liters per second (L/s))] in the uppermost aquifer.

Groundwater in lithologic units underlying the upper sandstone unit of the Burro Canyon Formation (uppermost aquifer) is protected from potential site-related contamination by hydrogeologic isolation. Low permeability mudstone units separate the three (upper, middle, and lower) sandstone units of the Burro Canyon Formation, and upward vertical hydraulic gradients in the lower and middle sandstone units inhibit the downward migration of water. The proposed remedial action will ensure protection of human health and the environment.

5.1 HYDROGEOLOGIC CHARACTERIZATION

The DOE has characterized the hydrogeologic units, aquifer hydraulic and transport properties, tailings materials, geochemical conditions, and water use at the Slick Rock UC and NC processing sites and the Burro Canyon disposal site. Major points are discussed in the following subsections. Attachment 3 describes in detail the hydrologic site characterization efforts.

5.1.1 Identification of hydrogeologic units

Processing site

The uppermost aquifer at the NC and UC sites consists of three hydrostratigraphic units: the Quaternary alluvium associated with the Dolores River floodplain deposits, the Slick Rock and Dewey Bridge Members of the Entrada Formation, and the Navajo Sandstone. A plan map of the NC and UC sites is provided in Figure 5.1. Figure 5.2 provides a stratigraphic cross section transecting both the UC and NC processing sites. Groundwater flow is unconfined in the alluvium and is expected to be semiconfined to confined in the underlying Entrada Formation and unconfined to semiconfined in the Navajo Sandstone Formation. These three formations are believed to be hydraulically connected, based on lithologic data and groundwater levels. Groundwater

FIGURE 5.1
MONITOR WELL LOCATION MAP OF THE UC AND NC PROCESSING SITES, SLICK ROCK, COLORADO

FIGURE 5.2
STRATIGRAPHIC CROSS SECTION AT THE UC AND NC PROCESSING SITES,
SLICK ROCK, COLORADO

elevations in the alluvium, Entrada Formation, and Navajo Sandstone remain relatively constant and do not show seasonal fluctuations.

The Dolores River alluvium is composed of unconsolidated clayey sands, sandy gravels, and cobbles from the ground surface to an approximate depth of 20 ft (6 m) at both the UC and NC sites. Quaternary alluvium materials also cap the tops of terraces surrounding the Dolores River floodplain. However, the occurrence of groundwater in the alluvium at the processing sites is limited to the recent channel and paleochannels of the Dolores River. The depth to groundwater at both processing sites ranges from 10 to 20 ft (3 to 6 m) in wells screened in the alluvium and is approximately the same as the surface water level of the Dolores River. Groundwater flow in the alluvium is generally to the north.

Jurassic Entrada Formation underlies the alluvium in the Dolores River floodplain and underlies the Summerville Formation in terraced areas adjacent to the floodplain. The canyon walls of these terraces consist of sandstones, mudstones, and shales of the Summerville Formation. Two members of the Entrada Formation are present: the Slick Rock Member and the Dewey Bridge Member. The Slick Rock Member is composed of light brown fine-grained sand that is generally not well cemented and therefore, erodes easily. The Dewey Bridge Member of the Entrada Formation underlies the Slick Rock Member at the NC processing site and directly underlies Dolores River alluvium at the UC site, where the Slick Rock Member is absent. Consisting of reddish-brown clayey siltstone, very fine-grained sandstone, and shale, the Dewey Bridge Member is more impermeable than the Slick Rock Member. The Dewey Bridge and Slick Rock Members of the Entrada Formation were encountered beneath the alluvial deposits to depths ranging from 20 to 160 ft (6 to 49 m). Groundwater movement is generally to the east in the Entrada Formation. The static groundwater elevations are higher in the Entrada Formation than in the overlying alluvium, suggesting the existence of a local, upward vertical gradient.

The Navajo Sandstone Formation underlies the Entrada Formation throughout the Slick Rock area at depths ranging from 53 to 170 ft (16 to 52 m) below the surface. The Navajo Sandstone is composed of light-brown to reddish-brown, fine-grained sandstone. The direction of groundwater flow in the Navajo Sandstone is generally to the north at both processing sites. Variability in the directions of the groundwater flow is expected to be a result of preferential flowpaths caused by differences in subsurface material permeability in and adjacent to the ancient buried channel of the Dolores River. The static groundwater elevations suggest that groundwater in the Navajo Sandstone is believed to be unconfined to semiconfined, depending upon the permeability and thickness of the overlying hydrostratigraphic units. Because the bottom of the Navajo Sandstone was not encountered in any of the DOE borings, the thickness of the Navajo Sandstone has not been determined directly in the area of the Slick Rock processing sites. However, Shawe *et al.* (1968) report the Navajo Sandstone Formation ranges from 0 to 420 ft (128 m) thick in the Slick Rock district.

Disposal site

A site plan with hydrogeologic testing locations at the proposed Burro Canyon site is shown in Figure 5.3. Four hydrostratigraphic units consisting of one unsaturated unit and three saturated units underlie the proposed disposal site, as shown in the hydrogeologic cross section in Figure 5.4. The unsaturated hydrostratigraphic unit is the lowest unit of the Dakota Sandstone and the uppermost Burro Canyon claystones and mudstones. The three saturated sandstone units within the Burro Canyon Formation are at approximate depths of 100, 200, and 300 ft (30, 60, and 90 m) and are described as the upper, middle, and lower units, respectively. These units are composed of fine- to medium-grained sandstone layers ranging from 20 to 75 ft (6 to 23 m) in thickness. The sandstone layers are hydrogeologically separated from one another by interbedded mudstone and siltstone units approximately 25 to 75 ft (8 to 23 m) thick.

The lowest unit of Dakota Sandstone consists primarily of low-permeability carbonaceous shale and mudstone. Two thin sandstone layers approximately 1 to 6 ft (0.3 to 1.8 m) thick are interbedded with the shales and mudstones in the lower Dakota Sandstone.

Groundwater in the upper sandstone unit of the Burro Canyon Formation is semiconfined and the yield is very low. The top of the upper sandstone unit is 77 to 99 ft (23 to 30 m) below the surface. The depth to the water table ranges from 75 to 110 ft (23 to 34 m). Measured groundwater elevations have remained constant over time. The upper sandstone unit is not a current or potential source of drinking water because the quantity of water available is less than 150 gpd (7×10^{-3} L/s), as evidenced by on-site aquifer performance tests. As a result, the groundwater in the upper sandstone unit is limited use (Class III) groundwater, as defined in 40 CFR 192.11(e) of the EPA proposed groundwater standards.

The middle sandstone unit is a confined aquifer approximately 53 ft (16 m) thick. It is overlain by approximately 60 to 70 ft (18 to 21 m) of laterally extensive mudstone. The top of the middle sandstone unit occurs between 170 and 191 ft (52 to 58 m) below the surface in the vicinity of the disposal cell footprint. The potentiometric surface is approximately 40 ft (12 m) above the top of the middle sandstone unit, resulting in an upward hydraulic gradient.

The lower sandstone unit of the Burro Canyon Formation is 39 ft (12 m) thick beneath the disposal cell, and the top of the unit is approximately 305 ft (93 m) below the surface. Groundwater in this unit is confined by the thick sequence of overlying low-permeability mudstones and siltstones of the Burro Canyon Formation and has an upward gradient with the potentiometric surface averaging 52 ft (16 m) above the middle sandstone unit.

The source of recharge is approximately 0.25 to 0.75 mi (0.4 to 1.2 km) northeast of the site. Sandstone beds outcrop along the east limb of the

FIGURE 5.3
MONITOR WELL LOCATION MAP AND NORTH-SOUTH (A-A') CROSS
SECTION AT THE BURRO CANYON DISPOSAL SITE, COLORADO

FIGURE 5.4
STRATIGRAPHY ALONG THE NORTH - SOUTH (A - A') CROSS SECTION
SLICK ROCK, COLORADO

Disappointment syncline and intercept tributaries to the Nicholas Wash drainage system. Groundwater then flows to the south-southeast and eventually dissipates (discharges) into the surrounding geologic strata south of the Burro Canyon disposal site.

5.1.2 Hydraulic and transport properties

Processing sites

Slug tests were conducted in the shallow alluvium and in the Navajo Sandstone at the NC and UC processing sites in 1986 and 1987. The middle hydrostratigraphic unit, the Entrada Formation, was not tested. Table 5.1 shows the hydraulic conductivities estimated for the Dolores River alluvium and the Navajo Sandstone at the Slick Rock, Colorado, processing sites.

Table 5.1 Average hydraulic properties at the processing sites

Characteristic	Dolores River alluvium	Entrada Formation	Navajo Sandstone
Average hydraulic conductivity (UC)	14 ft/day (5×10^{-3} cm/s)	Not determined	2×10^{-2} ft/day (8×10^{-6} cm/s)
Average hydraulic conductivity (NC)	23 ft/day (8×10^{-3} cm/s)	Not determined	Not determined
Average linear groundwater velocity (UC)	150 ft/yr (2.4×10^{-4} cm/s)	Not determined	1 ft/yr (1×10^{-6} cm/s)
Average linear groundwater velocity (NC)	100 ft/yr (1.5×10^{-4} cm/s)	Not determined	Not determined

The average linear groundwater velocity in the alluvium at the NC site was estimated to be 100 ft per yr (ft/yr) (1.5×10^{-4} cm/s), based on an average hydraulic conductivity of 23 ft/day (8×10^{-3} cm/s), a hydraulic gradient of 0.003, and an effective porosity of 0.25 for sand and gravel (Freeze and Cherry, 1979). The average linear groundwater velocity in the alluvium at the UC site is estimated to be 150 ft/yr (2.4×10^{-4} cm/s), based on an average hydraulic conductivity of 14 ft/day (5×10^{-3} cm/s), a hydraulic gradient of 0.008, and an effective porosity of 0.25. The Dolores River alluvium is recharged by seepage from the Dolores River upstream of the NC site and by precipitation. Groundwater discharges from the alluvium into the Dolores River downgradient of the UC site.

The average linear groundwater velocity of the Navajo Sandstone also is considerably lower than that of the alluvium. The calculated average linear groundwater velocity in the Navajo Sandstone is 1 ft/yr (1×10^{-6} cm/s), based

on an average hydraulic conductivity of 2.4 ft/day (8.5×10^{-6} cm/s) under a hydraulic gradient of 0.02 and an estimated effective porosity of 0.30 (Cooley *et al.*, 1969). The Navajo Sandstone is expected to be recharged by seepage from the Dolores River and overlying stratigraphic units. Groundwater discharges into surrounding stratigraphic units downgradient of the site.

Disposal site

Table 5.2 presents average aquifer parameters and average linear groundwater velocities for the Dakota Sandstone and the Burro Canyon Formation. The hydraulic conductivities of the unsaturated Dakota Sandstone bedrock and the unsaturated Burro Canyon mudstones were determined by field packer tests. The average horizontal hydraulic conductivity of the lower Dakota Sandstone Formation was 4.3×10^{-1} ft/day (1.5×10^{-4} cm/s), and the average horizontal hydraulic conductivity of the Burro Canyon mudstones was 6.5×10^{-3} ft/day (2.3×10^{-6} cm/s). Packer tests indicate that the saturated horizontal hydraulic conductivity of the Dakota Sandstone is moderate, and is several orders of magnitude greater than the Burro Canyon mudstone. The hydraulic conductivity decreases with depth in the Burro Canyon mudstone, reflecting decreased fracture permeability with depth.

Table 5.2 Average hydraulic properties at the proposed disposal site

Characteristic	Dakota Sandstone	Burro Canyon mudstone	Burro Canyon Formation Sandstone units		
			Upper	Middle	Lower
Hydraulic conductivity	4×10^{-1} ft/day (2×10^{-4} cm/s)	7×10^{-3} ft/day (2×10^{-6} cm/s)	4×10^{-2} ft/day (1×10^{-5} cm/s)	9×10^{-2} ft/day (3×10^{-5} cm/s)	5×10^{-3} ft/day (2×10^{-6} cm/s)
Average linear groundwater velocity (UC)	NA	NA	5.5 ft/yr (5×10^{-6} cm/s)	2.5 ft/yr (2×10^{-6} cm/s)	1.0 ft/yr (1×10^{-6} cm/s)

NA - Not applicable.

The average linear groundwater velocity in the Burro Canyon upper sandstone unit was estimated to be 5.5 ft/yr (5×10^{-6} cm/s), based on an average hydraulic conductivity of 4×10^{-2} ft/day (1×10^{-5} cm/s), a hydraulic gradient of 0.038, and an effective porosity of 0.10. Groundwater flow is to the southeast along the axis of the Disappointment syncline.

The average linear groundwater velocity of the Burro Canyon middle sandstone unit is 2.5 ft/yr (2×10^{-6} cm/s), assuming an average hydraulic conductivity of 9×10^{-2} ft/day (3×10^{-5} cm/s), a hydraulic gradient of 0.015, and an effective porosity of 0.20. The confined conditions in this unit create a substantial upward hydraulic potential. The potentiometric surface of the middle unit averages 42 ft (13 m) above the top of the sandstone unit. This potentiometric surface, however, is not higher in elevation than the overlying potentiometric surface measured in monitor wells screened in the upper sandstone unit. The

direction of groundwater flow is to the southeast. Recharge to the middle sandstone unit occurs upgradient from the disposal cell, approximately 0.25 to 0.75 mi (0.4 to 1.2 km) northeast of the site. Sandstone beds outcrop along the east limb of the Disappointment syncline and intercept tributaries to the Nicholas Wash drainage system. Groundwater then flows to the south-southeast and eventually dissipates (discharges) into the surrounding geologic strata south of the Burro Canyon disposal site.

The average linear groundwater velocity in the Burro Canyon lower sandstone unit is 1.0 ft/yr (4.8×10^{-7} cm/s), assuming a hydraulic conductivity of 5.0×10^{-3} ft/day (1.7×10^{-6} cm/s), a gradient of 0.05, and an effective porosity of 0.10. Groundwater in this unit is confined by the thick sequence of overlying low-permeability mudstones and siltstones of the Burro Canyon Formation. Groundwater has an upward gradient with the potentiometric surface 169 to 240 ft (52 to 73 m) above the top of the lower sandstone unit and averaging 52 ft (16 m) above the middle sandstone unit. The lower sandstone unit has an extremely low velocity and well yield. Vertical recharge to and discharge from the lower sandstone unit is restricted because the low-permeability interbedded claystone and siltstone strata impede infiltration.

5.1.3 Geochemical conditions

Processing site

Background groundwater quality is defined as the quality of groundwater expected at the site if uranium processing had not occurred. Background groundwater quality is characterized as follows for each of the three hydrostratigraphic units:

Dolores River alluvium. Background groundwater quality in the alluvial materials is characterized as a calcium sodium sulfate type at both the NC and UC sites. Total dissolved solids (TDS) concentrations measured in alluvial background monitor wells range from 622 milligrams per liter (mg/L) to 1180 mg/L. TDS averages 802 mg/L at the NC site and 986 mg/L at the UC site. The background pH ranges from 6.9 to 7.7. Concentrations or activities of chromium, molybdenum, uranium, and Ra-226 and -228 exceeded the maximum concentration limits (MCL) in one or more background alluvial monitor wells.

Entrada Formation. Background groundwater quality of the Entrada Formation is characterized as a calcium bicarbonate to sodium bicarbonate type. The pH of groundwater in the Entrada is slightly above neutral ranging from 7.8 to 8.0. TDS concentrations measured in the Entrada background monitor wells range from 147 mg/L to 1990 mg/L. Selenium and Ra-226 and -228 exceeded their respective MCLs in groundwater samples collected from the background monitor wells screened in the Entrada Formation.

Navajo Sandstone. Background groundwater quality in the Navajo Sandstone is characterized as a sodium bicarbonate type at the NC site and a magnesium bicarbonate type at the UC site. The pH of groundwater measured in background monitor wells screened in the Navajo Sandstone ranges from 7.2 to 7.8 for both processing sites. TDS concentrations are generally lower at the UC site (ranging from 229 to 1160 mg/L) than at the NC site (ranging from 492 to 1530 mg/L). The MCLs for chromium, molybdenum, Ra-226 and -228, selenium, silver, and uranium were equaled or exceeded on one or more occasions in Navajo Sandstone monitor well samples.

Tailings

The NC tailings site consists of the tailings pile and windblown contaminated areas, covering approximately 12 ac (4.9 ha). The tailings primarily consist of sandy gravel, sand, and silty sand. At the UC site, the tailings pile and surrounding contaminated land cover 55 ac (22 ha). The tailings consist of mostly fine- to medium-grained sand with some clayey sand and silt. The tailings material is finer-grained at the UC site than at the NC site. Seepage from the tailings has contaminated the groundwater in the alluvium beneath both the NC and UC sites.

The chemical characteristics of the NC and UC tailings materials were evaluated by pore fluid sampling with suction lysimeters. The pH of the tailings pore fluid is near neutral, ranging from 6.2 to 7.8. The TDS concentrations range from 2430 to 33,900 mg/L. Average concentrations of arsenic, cadmium, molybdenum, net gross alpha, selenium, and uranium exceeded the MCLs in lysimeter samples collected from the NC site. At the UC site, the average pore fluid concentrations of cadmium, molybdenum, nitrate, selenium, and uranium exceeded the MCLs.

On-site and downgradient (baseline) water quality has been compared to that of background groundwater. Average TDS concentrations in baseline alluvial groundwater are approximately 3 times those of background. The primary regulated hazardous constituents of concern in the Dolores River alluvium are molybdenum, nitrate, selenium, and uranium at the UC processing site and selenium and uranium at the NC processing site. The baseline water quality of the Entrada Formation also appears to be affected by uranium processing activities; the average concentrations of TDS in baseline Entrada monitor wells are approximately 3 times those observed in background Entrada monitor wells and concentrations of selenium exceed the MCL and background. Baseline water quality in the Navajo Sandstone does not appear to be affected by processing activities. TDS, pH, and the regulated constituents show minimal variation between background and baseline water quality.

Disposal site

Groundwater quality data were characterized individually for each sandstone unit in the Burro Canyon Formation because the units are hydrogeologically

separated from one another. Groundwaters in the upper and middle Burro Canyon sandstone units have been classified as sodium sulfate bicarbonate. In contrast, groundwater in the lower Burro Canyon Sandstone unit is sodium bicarbonate. Groundwater pH is near neutral to slightly above neutral, ranging from 7.5 to 9.1 in the upper sandstone unit, 7.2 to 7.6 in the middle sandstone unit, and 8.6 to 9.6 in the lower sandstone unit. TDS concentrations tend to decrease with depth, ranging from 598 to 945 mg/L in the upper sandstone unit, 460 to 658 mg/L in the middle sandstone unit, and 281 to 336 mg/L in the lower sandstone unit.

Naturally occurring selenium and Ra-226 and -228 have equalled or exceeded the proposed EPA MCLs in monitor wells screened in the upper sandstone unit. In addition, the EPA MCL for Ra-226 and -228 was slightly exceeded in one monitor well screened in the middle sandstone unit, in a one-time occurrence.

5.1.4 Characterization methods

The DOE characterized the hydrogeologic setting of the processing and disposal sites by installing monitor wells, collecting water level data from these monitor wells and performing hydraulic testing of the properties, tailings source term characterization through pore water analyses, and periodic groundwater quality analyses from select monitor wells. Attachment 3 provides details of these characterization efforts. The characterization programs conducted by DOE followed procedures outlined in the standard operating procedures for the UMTRA Project (JEG, n.d.) and the TAD (DOE, 1989a).

Groundwater quality was characterized by analyzing constituents listed in Table 8.1 of the TAD (DOE, 1989a). The standard operating procedures for the UMTRA Project (JEG, n.d.) outlines procedures for sampling, preserving, storing, and analyzing samples, including QA and QC protocols.

Attachment 3 provides a statistical treatment of groundwater quality in the uppermost aquifer at both the processing and disposal sites. The statistical analyses include the minimum, mean, median, maximum, percentage of nondetects, and the 98-percent confidence interval for background, on-site, and downgradient groundwater quality. Groundwater quality can be characterized by describing an average concentration and a statistical maximum. The procedures for calculating average and statistical maximum concentrations are discussed in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities—Interim Final Guidance* (EPA, 1989) and are described in the TAD. Average concentrations of hazardous constituents are represented statistically by a mean or median, depending on the proportion of nondetects, the distribution of the water quality data, and the number of samples available. The following guidelines apply:

- If the coefficient of variation of the data is greater than 1, the distribution is assumed to be lognormal and the geometric mean is reported.

- If the coefficient of variation of the data is less than 1, the distribution is assumed to be normal and the arithmetic mean is reported.
- If more than 15 percent of the data are below detection, the median is reported.
- If fewer than four samples are available, the median is reported.
Distribution types are unknown if fewer than four samples are reported.

The statistical maximum is the upper limit of the 98-percent confidence interval for the true average concentration assuming normal or lognormal distributions. A nonparametric upper confidence interval is used if more than 15 percent of the data are below detection. If fewer than four samples are reported, the maximum observed concentration is chosen as a statistical maximum. When most of the data are below detection, the reported statistical maximum may be the detection limit divided by two, as computed by the UMTRA Software Program for Environmental Analysis and Reporting (SPEAR) system (DOE, 1992). When the statistical values calculated are below the actual laboratory detection limits, the laboratory detection limits reported in Table 8.1 of the TAD (DOE, 1989a) are applied.

Processing sites

Site-specific studies that addressed groundwater at the Slick Rock NC and UC processing sites were initiated in 1981. Ford, Bacon & Davis Utah Inc. (FBDU, 1981) conducted an engineering assessment. The DOE initiated a reconnaissance investigation of the Slick Rock NC and UC sites in November 1984. Initial hydrogeologic characterization efforts at the processing sites continued through 1986. These investigations included the installation of six shallow monitor wells in the Dolores River alluvium, four deep monitor wells in the Navajo Sandstone, nine auger borings to the top of bedrock, and three test pits. From this limited hydrogeological characterization, it appeared that the Navajo Sandstone was confined by the Entrada Formation and an upward potentiometric gradient existed from the Navajo Sandstone Formation into the Entrada Formation.

Additional site characterization at the UC site continued during 1987. Related field activities included excavating 22 test pits, conducting surface geophysics, drilling 10 borings, and packer testing 2 boreholes in the Entrada Formation. The DOE drilled one borehole and installed three monitor wells in the Entrada Formation in 1989. Unconfined, near-surface groundwater was encountered in these monitor wells. Additional drilling in the Entrada indicated the presence of buried paleochannels incised by the ancestral Dolores River. In August 1989, the DOE completed a seismic refraction survey across the UC processing site. Paleochannels and river terraces buried by more recent deposits were verified as a result of this survey. In addition, the data produced from these field activities suggested that the Entrada Formation was not laterally extensive across the site

and did not completely separate the Dolores River alluvium from the Navajo Sandstone, as was previously thought.

To more accurately define these subsurface features, the DOE initiated a final site characterization drilling program. Monitor wells (10) and exploratory boreholes (12) were installed in September 1989. This program identified 1) the locations, dimensions, and gradients of a dual-forked paleochannel; 2) numerous terraces associated with the incision of the Dolores River; 3) the presence of unconfined, near-surface groundwater in the Entrada Formation and the Navajo Sandstone across parts of the UC processing site; and 4) the susceptibility of the Navajo Sandstone aquifer to contamination, due to localized erosion of the Entrada Formation confining beds. As a result, it was concluded that the Entrada Formation was not a laterally extensive confining unit as was originally thought. Additional information regarding groundwater occurrence and hydraulic properties is provided in Sections 3.1.3 and 3.1.4 of Attachment 3. Tables 3.1 and 3.2 of Appendix A of Attachment 3 provide monitor well construction information for the NC and UC processing sites, respectively. Appendix B of Attachment 3 provides lithologic logs and construction information for all DOE monitor wells.

Groundwater elevations were measured and water table maps were constructed to determine the direction of groundwater flow and hydraulic gradients. Slug tests were performed in the shallow alluvial material and in the Navajo Sandstone to estimate hydraulic conductivity. Sediment, tailings, surface water, groundwater, and lysimeter pore fluid samples were collected at the NC and UC processing sites and analyzed to characterize existing conditions. Lysimeter pore fluid samples were analyzed to characterize the tailings source term. Groundwater samples have been used to establish the nature and extent of contamination caused by uranium processing activities. The frequency and duration of sample collection is a function of when the monitor wells were installed, their proximity to the processing sites, and water quality data.

Disposal site

Three site-specific hydrologic investigations have been conducted in the vicinity of the Burro Canyon disposal site. In 1985, preliminary testing was conducted southeast of the current Burro Canyon disposal site location. Eight test pits and three boreholes were excavated to determine whether the location was suitable as a relocated disposal site. The area was found to be suitable for tailings disposal, as reported in the *Comparative Analysis of Disposal Site Alternatives Report for the UMTRA Project Slick Rock Sites Located at Slick Rock, Colorado* (DOE, 1986).

A second detailed site investigation was conducted during 1990 and 1991 at the current Burro Canyon site. During 1990, the DOE installed 16 monitor wells, 6 boreholes, and 21 test pits to characterize lithology, groundwater elevations and hydraulic gradients, aquifer properties, and groundwater quality at the disposal site.

Additional testing was conducted in 1991 in response to two issues raised by the Colorado Department of Health (CDH): 1) the extent of the mudstone aquitard between the upper and middle sandstone units of the Burro Canyon Formation southeast (downgradient) of the proposed disposal site, and 2) the degree of downgradient saturation in the upper sandstone unit. An exploration corehole was drilled approximately 900 ft (300 m) from the edge of the disposal cell to a total depth of 179 ft (54 m) below the surface. The exploration corehole confirmed that the Burro Canyon mudstone and sandstone units were continuous. A monitor well placed approximately 10 ft (3 m) north of the exploration corehole was completed to the base of the upper Burro Canyon sandstone unit for a total depth of 113 ft (34 m). A second monitor well, placed approximately 650 ft (198 m) southeast of the edge of the proposed disposal cell, was drilled through the upper sandstone unit [from 72 to 101 ft (22 to 31 m)] and the mudstone aquitard [from 101 to 169 ft (31 to 52 m)] and 10 ft (3 m) into the middle sandstone unit for a total depth of 179 ft (54 m). This well was then backfilled with bentonite and a screen was installed at the base of the upper sandstone unit from 80 to 100 ft (24 to 30 m), with filter pack material from 65 to 102 ft (20 to 31 m). Geophysical logs (natural gamma, gamma-gamma, neutron, and resistivity) were run in the exploratory borehole and five DOE monitor wells.

Table 3.41, Appendix A of Attachment 3, presents monitor well information. Appendix B of Attachment 3 provides the lithologic logs and monitor well construction information.

The chemical and mineralogical properties of Burro Canyon sediment samples were characterized in 1990 by Pittsburgh Mineral & Environmental Technology, Inc. (PMET, 1990). Sediment samples were collected from the Dakota Sandstone Formation (sandstones and shales) and from Burro Canyon Formation (mudstones and sandstones). The laboratory work included chemical analyses, polarized light microscopy with modal analyses, chemical analyses, and X-ray diffraction analyses.

Relatively undisturbed samples were recovered for visual inspection and laboratory tests to determine unsaturated hydraulic conductivity, porosity, and other selected parameters. Five sediment samples were collected from sandstones and shales of the Dakota Sandstone and mudstones and sandstones of the Burro Canyon Formation. Laboratory analyses were conducted to determine moisture contents, bulk densities, porosities, saturated hydraulic conductivities, soil moisture retention curves, and particle densities (Daniel B. Stephens & Associates, Inc., 1991).

Groundwater elevations were measured to map the potentiometric surface to determine the direction of groundwater flow and hydraulic gradients. Bailer recovery tests, aquifer performance tests, and slug injection tests were conducted to determine hydraulic parameters of the upper, middle, and lower Burro Canyon sandstone units. Water quality samples collected from selected

wells in the Burro Canyon sandstone units established background water quality at the disposal site.

5.1.5 Water use

Processing site

Eleven domestic wells are registered in the vicinity of the Slick Rock tailings sites, nine of which are no longer in use. One of the eleven wells, completed in the Navajo Sandstone, the Entrada Formation, and the alluvium, is potentially available to supply drinking water to a gas sweetener plant adjacent to the UC site. The other well, completed in the Navajo Sandstone upgradient of the NC and UC processing sites currently supplies water to Slick Rock businesses. An unregistered well, completed in the Navajo Sandstone, supplies water to a local resident. All these wells are hydrologically upgradient from the UC tailings site. A groundwater flow boundary appears to follow the course of the Dolores River and is expected to hydrogeologically separate the active unregistered well from the NC tailings, which are on the opposite side of the Dolores River from the unregistered well. As a result, none of these wells are expected to be affected from the tailings materials at the Slick Rock processing sites.

Surface water from the Dolores River is another potential source of water in the processing site vicinity.

Disposal site

No known registered or private wells are actively used within the upper sandstone unit of the Burro Canyon Formation within a 2-mi (3-km) radius of the Burro Canyon disposal site.

Groundwater development in the vicinity of the disposal site should not increase over the next 50 yr, because there is not enough water available to support development on any time scale. The first saturated hydrostratigraphic unit, the upper sandstone unit, has a low yield (less than 150 gpd), and is therefore classified as Class III (limited use) in accordance with Part 40 CFR 192.11(e) of the EPA groundwater protection standards. By definition, Class III groundwater is not a current or potential source of drinking water.

5.2 CONCEPTUAL DESIGN FEATURES FOR WATER RESOURCES PROTECTION

This section summarizes the principal design features of the proposed disposal cell at the Burro Canyon disposal site. Section 3.2 describes in detail the design features of the proposed disposal cell. The design features will ensure compliance and do not rely on active maintenance to ensure adequate long-term performance. Additional details and specifications of the conceptual design are provided in Attachment 1.

The disposal cell will hold approximately 620,000 yd³ [470,000 cubic meters (m³)] of contaminated material, and cover an area approximately 610 ft (186 m) wide and 905 ft (276 m) long along the southwest face of the mesa. The height of the cell will range from 30 ft (9 m) to 50 ft (15 m) above the existing ground surface. The completed disposal cell will occupy an area of 12 ac (4.9 ha). A buffer area of 53 ac (21 ha) would bring the total to 65 ac (26 ha). The DOE will schedule long-term surveillance of the disposal area.

The disposal cell cover will have a rock riprap surface layer and additional components below the rock. A detailed schematic of the cover is shown in Attachment 1, Drawings SRK-DS-10-0335 and SRK-DS-10-0336.

The design for the disposal embankment cover consists of the following layers, in descending order:

- Erosion protection layer. A layer of riprap [8 to 12 in (20 to 30 cm)] will prevent erosion of the disposal cell by surface water runoff.
- Bedding layer. A 6-in (15-cm)-thick sand/gravel bedding layer will prevent displacement of large diameter rock, protect the underlying frost protection layer from erosion, and drain water laterally.
- Frost protection layer. A 2.0-ft (0.6-m)-thick frost protection layer, consisting of fine-grained soil with some sand, will protect the radon/infiltration barrier from the effects of freezing and thawing.
- Radon barrier layer. A 2.0-ft (0.6-m)-thick sandy clay radon barrier will inhibit radon emanation and reduce infiltration through the underlying contaminated material.

The material properties and available quantities for the cover materials have been adequately defined to conform with the applicable provisions of the SRP. In addition, the performance of the cover system has been evaluated using both state-of-the-art techniques and standard engineering methods. The results indicate the cover will remain effective for a period of time that is in compliance with the EPA standard 40 CFR Part 192.02 for long-term performance.

Natural, stable materials have been proposed for use in constructing the Burro Canyon disposal cell to ensure long-term performance. Materials for the rock erosion protection layer have been selected, based on durability, suitability, and size, to perform adequately over the design life of the disposal cell. The compacted radon barrier material will be protected from erosion by the overlying cover components.

5.3 DISPOSAL

The proposed EPA standards in Subparts A and C of 40 CFR 192 require information and assessments to demonstrate that the disposal of RRM complies with groundwater protection and performance standards. The required information and assessments can be categorized as follows: the groundwater protection standard (see Section 5.3.1), a performance assessment, a closure performance standard (see Section 5.4), and a monitoring and corrective action program (see Section 5.5). The purpose of the groundwater protection and performance standards is to establish the minimum acceptable performance of the disposal and control of RRM to prevent or control future releases of hazardous constituents. The performance assessment confirms the adequacy of the disposal cell and provides corrective action that may be necessary if the disposal cell does not perform adequately (NRC, 1989). The following sections describe in detail the four components of the groundwater protection and performance standards.

5.3.1 Groundwater protection standard for disposal

The Burro Canyon disposal cell is designed to control radioactive materials and nonradioactive contaminants as required by the proposed EPA groundwater protection standards in 40 CFR 192.02(a)(3). The proposed groundwater protection compliance strategy applies supplemental standards for Class III (limited use) groundwater. Protection of human health and the environment will be achieved because the uppermost aquifer has a low yield [less than 150 gpd (7×10^{-3} L/s)] as demonstrated in on-site aquifer performance tests. No known potable supply wells exist within the uppermost aquifer in a 2-mi (3-km) radius of the disposal site. The uppermost aquifer is hydrogeologically isolated from underlying saturated units by thick [25- to 75-ft (8- to 23-m)] mudstone units and by significant upward vertical hydraulic gradients. A narrative supplemental standard is provided in Section 5.3.2.

The groundwater protection standard consists of three components: 1) a list of hazardous constituents, 2) a corresponding list of concentration limits for the constituents, and 3) a point of compliance (POC) (NRC, 1989). The DOE has identified hazardous constituents in the tailings pore fluids measured in lysimeter samples and in shallow alluvial groundwater at the processing sites. For this narrative supplemental standard application, no concentration limits or POCs have been established for the identified potentially hazardous constituents because the uppermost aquifer at the proposed Burro Canyon disposal site meets the insufficient yield criteria of Class III (limited use) groundwater, as defined in 40 CFR 192.11(e) of the EPA proposed groundwater standards. There is no historic or current beneficial use of groundwater in the upper sandstone unit of the Burro Canyon Formation. As a result, defining concentration limits and a POC would not further protect human health and the environment. A demonstration that the remedial action is as close as reasonable to meeting the otherwise applicable standard is presented in Section 5.3.2.

Hazardous constituents

Hazardous constituents at the Burro Canyon disposal site were identified from characterization of the tailings materials. A description of the uranium recovery process and an evaluation of groundwater quality data are included in Attachment 3.

Hazardous constituents potentially of concern at the Burro Canyon site have been determined, based on two criteria: 1) they must be present in, or reasonably expected to be present in, or derived from the RRM to be stabilized at the disposal site; and 2) they must be constituents listed in the proposed EPA groundwater protection standards (EPA, 1987).

Average concentrations or activities of eight inorganic hazardous constituents with MCLs that are related to uranium processing activities and exceeded laboratory method detection limits in the lysimeter pore fluid samples from the NC or UC sites include arsenic, cadmium, lead, molybdenum, net gross alpha, nitrate, selenium, and uranium. Six additional hazardous constituents without MCLs which exceeded the laboratory method detection limits are antimony, copper, thallium, tin, vanadium, and zinc. Table 5.3 summarizes the hazardous constituents identified at the Slick Rock processing sites.

Groundwater at the processing site was screened for the organic hazardous constituents. One organic screening groundwater sample was collected from a DOE monitor well at the Slick Rock NC processing site and another was collected from a DOE monitor well at the UC Slick Rock processing site. No organic hazardous constituents were detected in the monitoring well sample collected from the UC processing site. Two organic compounds were detected in NC groundwater sample; however, the concentrations of the detected organic compounds are believed to be the result of laboratory contamination, rather than from the processing operations at the NC Slick Rock Uranium Mill Tailings Remedial Action (UMTRA) Project site. Additional discussion is provided in Section 3.1.6 of Attachment 3.

The DOE has evaluated the potential effects of relocating the tailings to the Burro Canyon disposal site and has determined that, because the uppermost aquifer has a low yield [less than 150 gpd (7×10^{-3} L/s)] and is not a current or potential source of water, hazardous constituents from the tailings source term will not affect human health and the environment. Furthermore, the disposal cell will minimize release of the potentially hazardous constituents identified in Table 5.3 (to the extent necessary to protect human health and the environment). Approximately 50 to 65 ft (15 to 20 m) of low-permeability [2.3×10^{-6} cm/s (6.5×10^{-3} ft/day)] interbedded mudstone and siltstone sequences will separate the base of the disposal cell from the uppermost aquifer (upper sandstone unit of the Burro Canyon Formation). As a result, if any potentially hazardous constituents are released below the disposal cell foundation, the low-permeability mudstone and siltstone sequences are expected to limit further migration. Additional discussion of potential points of exposure is presented in

Table 5.3 Summary of hazardous constituents identified at the Slick Rock processing sites^a

Parameter	Source term concentration (NC site)	Source term concentration (UC site)	Laboratory detection limit	MCL	Background ^b	
					Average	Stat. maximum
Constituents with MCLs						
Arsenic	0.068 ^c	0.022 ^c	0.01	0.05	0.01 ^d	0.01 ^d
Cadmium	0.045 ^c	0.084 ^c	0.001	0.01	0.001 ^d	0.001 ^d
Gross alpha (excluding radium and uranium ^e)	-1142.18 ^c	-21.19	1.0	15.0	0.845 ^c	6.96 ^c
Lead	0.03 ^c	0.01 ^c	0.01	0.05	0.01 ^d	0.01 ^c
Molybdenum	0.31 ^f	3.63 ^g	0.01	0.1	0.01 ^d	0.02 ^c
Nitrate (as NO ₃)	--	210.0	1.0	4.0	1.6 ^c	4.4 ^c
Selenium	4.73 ^f	2.78 ^g	0.005	0.01	0.005 ^d	0.012 ^c
Uranium	1.77 ^g	0.257 ^f	0.003	0.044	0.003 ^d	0.019 ^c
Constituents without MCLs						
Antimony	0.015 ^c	0.011 ^c	0.003	None	0.003 ^d	0.003 ^d
Copper	0.06 ^f	0.42 ^g	0.02	None	0.02 ^d	0.02 ^d
Thallium	0.02 ^c	0.01 ^d	0.01	None	0.01 ^d	0.01 ^d
Tin	0.099 ^c	0.009 ^c	0.005	None	0.005 ^d	0.005 ^d
Vanadium	4.83 ^g	0.18 ^g	0.01	None	0.01 ^d	0.02 ^c
Zinc	0.038 ^c	0.236 ^g	0.005	None	0.005 ^d	0.010 ^c

^aAll units are milligrams per liter (mg/L) unless otherwise noted. Source term concentrations are based on lysimeter samples collected from January 1989 to October 1992.

^bBackground groundwater quality in the Burro Canyon Formation, upper unit (uppermost aquifer).

^cNonparametric distribution.

^dStatistical values are below laboratory detection limits in Table 8.1 of the *Technical Approach Document* (DOE, 1989a).

^eUnits are picocuries per liter (pCi/L).

^fNormal distribution, mean is arithmetic.

^gLognormal distribution, mean is geometric.

Section 3.3. The uppermost aquifer is hydrogeologically isolated from the underlying water bearing units by low-permeability mudstone and upward vertical gradients, as discussed in Attachment 3.

Proposed concentration limits

To achieve compliance with the proposed EPA groundwater protection standards at the disposal site, the DOE proposes to apply a narrative supplemental standard based on Class III (limited use) groundwater due to insufficient yield in the uppermost aquifer. A narrative supplemental standard is reasonable for the Burro Canyon disposal site for the following reasons:

- The quantity of water available is less than 150 gpd (7×10^{-3} L/s) [40 CFR 192.11(e)(3)], as demonstrated by on-site aquifer performance testing.
- There is no historic or existing beneficial use of the groundwater in the uppermost aquifer, due to limited yield.
- The proposed disposal cell foundation will be separated from the uppermost aquifer by a thick layer of low-permeability mudstone [25 to 75 ft (8 to 23 m)].
- Groundwater in the sandstone units underlying the uppermost aquifer is protected from potential site-related contamination by the low-permeability mudstone units that inhibit the downward migration of water and steady state upward vertical hydraulic gradients in the lower and middle sandstone units of the Burro Canyon Formation.
- There is no evidence of discharge anywhere in the vicinity of the site; therefore, there is no point of exposure.
- The proposed remedial action at the Burro Canyon disposal site comes as close to meeting the otherwise applicable standards (40 CFR 192) as is reasonable under the circumstances (see Section 5.2 for a discussion of disposal cell design features for protection of groundwater). A discussion of how the remedial action at the Burro Canyon disposal site will protect human health and the environment is provided in Section 5.3.3.

Point of compliance

A POC has not been established for the proposed Burro Canyon disposal site for the reasons previously discussed.

5.3.2 Narrative supplemental standard

The NRC must consider the following four items before granting supplemental standards (NRC, 1989); 1) the criteria for applicability, 2) description of the supplemental standard, 3) demonstration that the remedial action satisfies the

proposed supplemental standard, and 4) demonstration that the supplemental standard is as low as reasonable under the circumstances. Items 1, 3, and 4 are discussed in this section. Item 2 is discussed in Section 5.3.1.

Applicability criteria

To achieve compliance with the proposed EPA groundwater protection standards, the DOE proposes the application of a narrative supplemental standard (Subpart C of 40 CFR 192) at the Burro Canyon disposal site. Groundwater in the uppermost aquifer meets the definition of Class III (limited use [40 CFR 192.11(e)]) based on insufficient yield and groundwater use. These criteria are discussed below.

The EPA defines "sufficient yield" as a quantity of water from a well or spring sufficient to meet the long-term needs of an average family (EPA, 1986). The yield must be sustainable into the future. The EPA has estimated that the lowest quantity that meets this requirement is 150 gpd (7×10^{-3} L/s). Groundwaters with yields less than this criterion are defined as Class III.

The groundwater protection standards in 40 CFR 192.02(a)(3) apply to the uppermost aquifer hydraulically downgradient from the disposal unit. The upper sandstone unit of the Burro Canyon Formation is the uppermost aquifer at the Burro Canyon disposal site. Groundwater in this unit occurs under semiconfined conditions at constant levels and does not show seasonal fluctuations. The upper sandstone unit is not a current or potential source of drinking water because the quantity of water available is less than 150 gpd (7×10^{-3} L/s), as evidenced by on-site aquifer performance tests. As a result, the groundwater in the upper sandstone unit is limited use, or Class III groundwater, as defined in 40 CFR 192.11(e) of the EPA's proposed groundwater standards. Furthermore, the upper sandstone unit is hydrogeologically isolated from the underlying middle and lower sandstone units, as discussed in Section 3.2.3 of Attachment 3.

By definition, Class III (limited use) groundwater is not a current or potential source of drinking water. No known registered or private wells are actively used within the upper sandstone unit of the Burro Canyon Formation in a 2-mi (3-km) radius of the Burro Canyon disposal site, because of limited yield. Furthermore, groundwater development in the vicinity of the disposal site should not increase over the next 50 yr, because there is not enough water available to support development on any time scale.

Demonstration that remedial action satisfies the proposed supplemental standard

This section describes potential impacts of groundwater use to human health and the environment. There are no historic or existing beneficial uses of groundwater in the upper sandstone unit of the Burro Canyon Formation, based on the applicability criteria discussed above.

Human health and the environment will be protected for the following reasons:

- The quantity of water available is less than 150 gpd (7×10^{-3} L/s) [40 CFR 192.11(e)(3)], preventing future groundwater development and use.
- Groundwater in the uppermost aquifer beneath the proposed Burro Canyon disposal site is not a current or potential source of drinking water.
- The proposed disposal cell foundation will be separated from the uppermost aquifer by 25 to 75 ft (8 to 23 m) low-permeability mudstone.
- The uppermost aquifer is hydrogeologically isolated from the underlying water-bearing units.
- There is no point of exposure downgradient of the disposal site. Details are provided in Section 5.3.3.

As low as reasonable under the circumstances

The proposed disposal cell design meets the as low as reasonable under the circumstances criterion. The design features, described in Section 5.2, will ensure that human health and the environment are protected. Active maintenance will not be required to ensure long-term performance. The proposed disposal embankment cover will use natural, stable materials to prevent surface erosion, provide protection against freezing and thawing, and inhibit radon emanation and water seepage, by incorporating design features that are as close to meeting the otherwise applicable standards as are reasonable under the circumstances.

5.3.3 Point of exposure

Pursuant to 40 CFR 192, this section assesses the potential for human and environmental exposure and concludes that the probability of exposure is low enough to prevent adverse impacts from groundwater contamination. For the purposes of this discussion, points of exposure can be divided into two categories: 1) surface expressions where water enters the uppermost aquifer as precipitation and outflows as surficially exposed drainage, and 2) subsurface drainage.

Surface points of exposure

The upper sandstone unit is recharged by infiltration of water from the surface outcrop upgradient of the site. Sandstone beds outcrop along the east limb of the Disappointment syncline and intercept tributaries to the Nicholas Wash drainage system. Groundwater movement in the upper sandstone unit parallels the axis of the Disappointment syncline, and eventually dissipates (discharges) into the Burro Canyon Formation southeast of the disposal site (Figure 5.5). The Burro Canyon Formation has a grade of approximately 3 percent. The Joe

Davis Canyon is about 1 mi (2 km) south of the disposal site. Based on a cross section shown in Figure 5.6 (modified from Shawe *et al.*, 1968), the upper sandstone unit of the Burro Canyon Formation is present only as a cap at the top of the Joe Davis Canyon. Any potential seepage into the Joe Davis Canyon from the Burro Canyon Formation is expected to be from the middle and/or lower Burro Canyon sandstone units. Furthermore, based on the direction of groundwater movement, the Joe Davis Canyon is cross gradient from the Burro Canyon disposal cell. Therefore, any potential leachate from the disposal cell would never reach Joe Davis Canyon.

Additional potential points of exposure include two thin sandstone layers of the Dakota Sandstone Formation that outcrop at the base of the disposal cell mesa within 200 to 300 ft (60 to 90 m) of the toe of the disposal cell. The disposal cell is designed to mitigate lateral seepage potential with a low permeability cover and the bottom of the excavation keyed to the low permeability mudstone of the Burro Canyon Formation. Excavating into the Burro Canyon Formation mudstone effectively creates a bottom and continuous sidewall liner under and around contaminated material. Therefore, the relatively small volume of leachate from the dry sand tailings is not expected to move laterally through the Dakota Sandstone layers and create seeps at the base of the mesa at the proposed Burro Canyon disposal site.

Subsurface points of exposure

Subsurface drainage potentially could result from transient drainage of excess moisture from the tailings. The tailings at the Slick Rock sites consist of sand and poorly graded sand with silt. The tailings saturated hydraulic conductivity is approximately 140 ft/day (5×10^{-2} cm/s), which is characteristic of a clean, free-draining sand (Freeze & Cherry, 1979). As a result, the tailings will have a low moisture content when they are placed in the disposal cell. This low moisture content of the RRM, coupled with a 2-ft (0.6-m)-thick radon barrier, will inhibit radon emanation and water seepage through the underlying contaminated material.

Approximately 50 to 65 ft (15 to 20 m) of low-permeability [6.5×10^{-3} ft/day (2.3×10^{-6} cm/s)] interbedded mudstone and siltstone sequences will separate the base of the disposal cell from the upper sandstone unit of the Burro Canyon Formation. Groundwater in lithologic units underlying the uppermost aquifer are also protected from potential seepage from the disposal cell by 1) hydrogeologic isolation, provided by the low-permeability Burro Canyon mudstone units that inhibit the downward migration of water, and 2) upward vertical hydraulic gradients in the lower and middle sandstone units of the Burro Canyon Formation.

5.4 PERFORMANCE ASSESSMENT AND DEMONSTRATION

The DOE is required to demonstrate that the performance of the disposal cell will comply with the EPA groundwater protection standard [40 CFR 192.02(a)(3)]. To achieve compliance, the DOE proposes to apply supplemental

NOTE: PORTION OF SECTION B-B' SHOWN BELOW
SHADED ON LOCATION MAP.

FIGURE 5.6
REPRESENTATIVE DIAGRAMMATIC SECTION OF STRATA
OF BURRO CANYON FORMATION

REFERENCE: FROM SHAW, DR. et al. 1968.

RAS

MAC: SITE/SRK/RAS/BURROXSEC

standards, because the uppermost aquifer is not a current or potential source of drinking water due to limited yield.

Aquifer performance testing has been conducted at the proposed Burro Canyon disposal site to assess the hydraulic properties and amount of interconnection between the saturated units of the Burro Canyon Formation. The results of these and other site-specific hydrogeologic investigations (described in Attachment 3) demonstrate that groundwater is protected from potential site-related contamination in the upper sandstone unit of the Burro Canyon Formation (uppermost aquifer) and in the underlying sandstone units. Hydrogeologic isolation is provided by the low-permeability mudstone units above and below the uppermost aquifer and by upward vertical hydraulic gradients in the middle and lower sandstone units of the Burro Canyon Formation.

The DOE has demonstrated that the proposed RAP at the disposal site will comply with Subpart A (40 CFR 192) of the proposed groundwater protection standards. The disposal cell will minimize the release of hazardous constituents to groundwater and surface water and of radon emissions to the atmosphere to the extent necessary to protect human health and the environment [40 CFR 192.02(a)(4)]. Natural, stable materials have been proposed for use in the construction of the disposal cell so that long-term performance is ensured (see Section 3.3). The DOE also has demonstrated that design features necessary for compliance with the groundwater protection standards minimize the need for further disposal site maintenance. Because sustainable amounts of groundwater are not available from the upper sandstone unit, no existing or potential users are in the area.

5.5 GROUNDWATER MONITORING

Pursuant to 40 CFR 192.02(a)(4)(b), this section addresses a groundwater monitoring plan to be carried out during and after the remedial action period. The DOE has determined that proposing concentration limits and monitoring a POC at the Burro Canyon disposal site would not further protect human health and the environment for the reasons discussed in Sections 5.3.1 and 5.3.2. An assessment of the potential effects to human health and the environmental exposure and a determination that the probability of exposure will be low enough to prevent adverse impacts from groundwater contamination are provided in Section 5.3.3. Points of exposure have been divided into two categories: 1) surface expressions where the source of recharge is precipitation and discharge is surficially exposed drainage, and 2) subsurface drainage. Groundwater monitoring would not be effective at the Burro Canyon disposal site, and is therefore not proposed, because insufficient yield in the uppermost aquifer will preclude its future use. The only point of exposure that could potentially affect human health or the environment would be surface seepage at the base of the disposal cell mesa. In lieu of groundwater monitoring, DOE will conduct long-term surveillance monitoring by conducting inspections to locate surface expressions of seepage at and in the vicinity of the Burro Canyon

disposal site. These visual inspections will include looking for physical evidence of mineralization, phreatophyte vegetation, and the presence of saturated zones at sandstone outcrops.

5.6 GROUNDWATER CLEANUP

The DOE is responsible for demonstrating compliance of cleanup or control of existing processing-related groundwater contamination at the Slick Rock sites with the proposed EPA groundwater protection standards in Subpart B of 40 CFR 192.

5.6.1 Groundwater cleanup standard

The current level of site characterization is sufficient to address only whether remedial action will comply with the draft final EPA groundwater protection standards. The DOE has decided that aquifer restoration (groundwater cleanup) will be addressed under a separate DOE program and will be part of a separate National Environmental Policy Act process. Additional groundwater characterization may be conducted to include water quality, groundwater flow, and aquifer properties. A conceptual groundwater restoration strategy will be developed.

The current level of characterization at the Slick Rock processing sites is sufficient to address only whether the remedial action will comply with Subpart A of the proposed EPA groundwater protection standards. Additional investigations will be conducted as necessary to determine the appropriate groundwater cleanup strategy for the Slick Rock processing sites. The proposed surface remedial action will not preclude or interfere with any potential groundwater remediation activities at these processing sites.

5.6.2 Cleanup demonstration

Demonstration of cleanup and control of existing processing-related groundwater contamination will be addressed under a separate DOE UMTRA Program and will be part of a separate process to comply with the National Environmental Policy Act. The proposed remedial action will not preclude or interfere with active groundwater restoration at the processing sites, should it be required, because the tailings will be relocated to a remote disposal site.

5.6.3 Cleanup monitoring program

Groundwater monitoring and site characterization will continue at the processing sites, as needed. Procedures for collecting, handling, and analyzing groundwater samples are outlined in the UMTRA standard operating procedures (JEG, n.d.) on file at the UMTRA Albuquerque Operations Office.

5.7 WATER RESOURCES PROTECTION STRATEGY SUMMARY

To achieve compliance with the proposed EPA groundwater protection standards (Subpart A of 40 CFR 192), the DOE proposes to apply supplemental standards for Class III (limited use) groundwater because of low yield [less than 150 gpd (7×10^{-3} L/s)] in the uppermost aquifer. The proposed remedial action will ensure protection of human health and the environment. A summary of the principal features of the water resources protection strategy for the Burro Canyon disposal site follows.

- Uranium tailings and associated contaminated materials at the UC and NC mill sites will be consolidated and relocated to the Burro Canyon disposal site. These materials will be placed in a partially belowgrade disposal cell designed to reduce radon emanation, resist degradation, reduce infiltration, and withstand differential settlement.
- The disposal cell foundation and the site location have been optimized to utilize favorable hydrogeologic and geochemical conditions of the site. A multiple-component cover has been included. The design for the disposal embankment cover consists of the following layers, in descending order: 1) riprap, to prevent erosion of the disposal cell by surface water runoff; 2) a sand and gravel bedding layer, to prevent displacement of large diameter rock, protect the underlying frost protection layer from erosion, and drain water laterally; 3) a frost protection layer (fine-grained soil with some sand), to protect the radon/infiltration barrier from the effects of freezing and thawing; and 4) a thick sandy clay radon barrier, to inhibit radon emanation and infiltration through the underlying contaminated material.
- The proposed groundwater protection compliance strategy applies supplemental standards. Because the demonstrated quantity of water available from the uppermost aquifer is less than 150 gpd (7×10^{-3} L/s), groundwater is classified as Class III (limited use). Class III groundwater refers to groundwater that is not a current or potential source of drinking water.
- Groundwater in lithologic units underlying the upper sandstone unit of the Burro Canyon Formation (uppermost aquifer) is protected from potential site-related contamination by 1) hydrogeologic isolation provided by the low permeability mudstone units that inhibit the downward migration of water, and 2) upward vertical hydraulic gradients in the lower and middle sandstone units of the Burro Canyon Formation.
- Groundwater monitoring would not be effective at the Burro Canyon disposal site, and is therefore not proposed, because insufficient yield in the uppermost aquifer will preclude its future use. The only point of exposure that could potentially affect human health or the environment would be surface seepage at the base of the disposal cell mesa. In lieu of

groundwater monitoring, DOE will conduct compliance monitoring by conducting inspections to locate surface expressions of seepage at and in the vicinity of the Burro Canyon disposal site. These visual inspections will include looking for physical evidence of mineralization, phreatophyte vegetation, and the presence of saturated zones at sandstone outcrops.

- Demonstration of cleanup and control of existing processing-related groundwater contamination at the UC and NC sites will be addressed under a separate DOE UMTRA Project program, and will be part of a separate process to comply with the National Environmental Policy Act. The proposed surface remedial action will not preclude or interfere with active groundwater restoration at the processing site, should it be required, because the tailings will be relocated to a remote disposal site.

6.0 RADON ATTENUATION AND SITE CLEANUP

6.1 INTRODUCTION

This section summarizes the disposal cell design and relevant parameters used to evaluate the radon barrier. The radiation survey plan is discussed to provide reasonable assurance that compliance with the EPA standards outlined in 40 CFR 192 will be achieved.

6.2 DESIGN

The proposed remedial action will consolidate contaminated materials from the NC and UC areas within the boundaries of the designated Slick Rock sites into a single disposal cell at the Burro Canyon site. The approximate volume of these contaminated materials is 620,000 yd³ (470,000 m³). In addition, an estimated 3000 yd³ (2000 m³) of uncontaminated demolition debris from the recreation building and other site structures and a large quantity of on-site scrap materials will be disposed of in the main disposal cell. Efforts will be made to place materials with relatively low Ra-226 concentrations over materials with higher concentrations. A compacted (95 percent) earthen radon barrier 24 in (60 cm) thick will be placed directly over the contaminated material. The sequencing of contaminated material within the cell and cover replacement will reduce the radon flux to below the EPA standards, to levels that are as low as reasonably achievable (ALARA).

Additional cover components will be sequentially placed above the primary earthen radon barrier. On the gradual topslope, these components will consist of a 2.0-ft (61-cm)-thick frost protection layer, a 6-in (15-cm)-thick bedding layer, and riprap layer ranging in thickness from 8 to 12 in (20 to 30 cm). The sideslopes will contain the same layers as the topslope; however, the sideslope riprap layer will be 1.0 ft (30 cm) thick.

The radon barrier, frost protection layer, and bedding layer will all contribute to the reduction of surface radon flux; however, only the radon barrier was considered in the radon diffusion calculations.

6.3 RADON BARRIER PARAMETERS

The radon barrier design parameters and support calculations were used in conjunction with the RAECOM model (NRC, 1984) to determine the cover thickness needed to control radon flux to meet the EPA standard of 20 pCi/m²s. Determination of the radon barrier thickness was based on procedures specified in the TAD (DOE, 1989a).

Specific parameters discussed below include long-term moisture content, radon diffusion, radon emanation, bulk density, specific gravity, porosity, layer thickness, and average Ra-226 concentrations. The RAECOM input parameters

for the Slick Rock materials are presented in Attachment 1, Calculation 11-321-01-00 (Radon Barrier Design).

As of the date this calculation was performed, analytical test data from some material properties are incomplete. Assumptions and empirical correlations have been used while additional field investigation and analytical testing are conducted. The radon barrier design parameters will be verified and/or revised upon completion of the additional investigation.

6.3.1 Long-term moisture

The average long-term moisture content for the earthen radon barrier and contaminated material was determined by using the optimum and capillary moisture content, the Rawls procedure, and the *in situ* residual moisture. In general, the lowest value obtained from the tests was selected to characterize the radon barrier. Three radon barrier soil samples from the Disappointment Valley borrow site were tested separately. The *in situ* residual moisture and minus 15 bar capillary moisture content were 11.6 and 15.5 percent by weight, respectively. Because the *in situ* moisture content is less than the capillary moisture content, it was conservatively selected to represent the barrier material's long-term moisture content.

Separate sample sets were tested from each of the representative areas of contamination to determine their respective long-term moisture content: the NC site (three samples) and the UC site (four samples). *In situ* moisture tests on these samples yielded conservative estimates for long-term moisture content; therefore, minus 15 bar capillary suction measurements were not conducted on these samples. The average moisture contents for the NC site and UC site were 10.3 and 5.3 percent moisture by weight, respectively.

6.3.2 Radon diffusion

Average radon diffusion coefficients for the earthen radon barrier material and contaminated materials were determined using three different cover soil samples and three and four soil samples from the NC and UC contaminated areas, respectively. Radon diffusion for each type of material was measured in the laboratory as a function of moisture content. For each soil sample, approximately six diffusion measurements were made, each at a different moisture content within the moisture content range. Test results for the cover and contaminated materials were plotted separately and a best fit to an analytical model curve was obtained for each material category using a least squares methodology. At 54-percent saturation (11.6 percent by weight), a radon diffusion coefficient of $1.1\text{E-}02 \text{ cm}^2/\text{s}$ was derived for the earthen component of the radon barrier. Diffusion coefficients of $2.6\text{E-}02$ and $1.9\text{E-}02 \text{ cm}^2/\text{s}$ were estimated for the UC tailings and offpile, respectively. A diffusion coefficient of $2.0\text{E-}02 \text{ cm}^2/\text{s}$ was estimated for the contaminated material from the NC site. Each diffusion coefficient value selected corresponds to the individual estimated long-term moisture content for the effective material.

6.3.3 Radon emanation

In general, radon emanation has been shown to be statistically independent of both moisture and Ra-226 concentrations using standard regression and statistical analysis. Twelve standard measurements of radon emanation for NC tailings-contaminated materials ranged from 0.23 to 0.62, with an arithmetic average of 0.42 and a standard error of ± 0.03 . Fourteen standard measurements of radon emanation for UC tailings-contaminated materials ranged from 0.10 to 0.29, with an arithmetic average of 0.19 and a standard error of ± 0.02 . Nine standard measurements of radon emanation for UC offpile-contaminated materials ranged from 0.31 to 0.59, with an arithmetic average of 0.45 and a standard error of ± 0.03 .

6.3.4 Dry densities and porosities

The dry densities, specific gravities, and porosities for the earthen radon barrier and contaminated materials were determined using standard tests, assuming a design compaction of 95 and 90 percent, respectively. Radon barrier soils had maximum dry densities ranging from 1.77 to 1.90 grams per cubic centimeter (g/cm^3) and specific gravities of 2.67 to 2.80, for separate measurements made on seven and five cover soil samples, respectively. An average density at 95-percent compaction of 1.73 g/cm^3 and an average specific gravity of 2.74 were used to obtain a representative porosity of 0.37 for the radon barrier.

Maximum dry density (22) and specific gravity (31) measurements of 30 samples of contaminated material ranged from 1.53 to 1.94 g/cm^3 and 2.55 to 2.75 , respectively. The respective average compacted density in g/cm^3 (90 percent compaction) and specific gravity for each contaminated area were 1.64 and 2.70 for the UC offpile and subpile areas (11 samples), 1.46 and 2.69 for the UC tailings area (10 samples), and 1.51 and 2.70 for the NC area (9 samples). The estimated porosities for contaminated soils from the UC offpile and subpile areas, UC tailings area, and NC area were 0.39 , 0.46 , and 0.44 , respectively.

6.3.5 Layer thickness

Specific thicknesses of three discrete layers of contaminated materials were calculated for NC site materials, UC tailings and subpile materials, and UC offpile materials. Thicknesses for the contaminated layers were calculated based on estimated volumes of materials and their ultimate geometric locations in the disposal cell, with layers sequentially placed in increasing numerical order from bottom to top. Volumes of materials were determined from radiometric measurements and radiological analyses of soil samples and from boring and test pit material collected across the Slick Rock sites. Information on layer thicknesses can be found in Calculations 11-212-01-01 and 11-321-02-00 of Attachment 1.

6.3.6 Radium-226 concentrations

Average Ra-226 concentrations were estimated based on an assessment of radiometric measurements (hand-held and borehole gamma logs), and radiochemical and gamma spectroscopic measurements of contaminated material collected from surface soil samples, test pits, and boreholes within each subarea. Incremental Ra-226 depth profiles were constructed at each measurement grid point within the subareas. The average Ra-226 concentration for each subarea was determined by integrating the profiles over the volume contained between the topographical surfaces defining the ground surface and the excavation depth required to comply with EPA cleanup standards. Estimated design volumes are shown in Table 1.1 of Section 1.0 of this document.

6.3.7 Ambient radon concentration

An ambient radon concentration in air of 1.5 pCi/L was used for the RAECOM computer code. The code was based on 24-hr background air samples collected with continuous radon samplers in the vicinity of the Slick Rock sites (FBDU, 1977). However, preremedial action radon monitoring at the disposal site for four quarters (August 1990 through August 1991) using integrating Track-Etch^R detectors indicates that an ambient radon concentration of 0.5 pCi/L is more appropriate (DOE, 1991).

6.4 EVALUATION OF RADON BARRIER

The radon barrier was evaluated for compliance with the EPA radon flux standard of 20 pCi/m²s using the above parameters in the RAECOM code. Only the high clay content earthen layer directly over the contaminated material was considered. A minimum thickness of 61 cm (24 in) is needed on the topslopes of the disposal cell to achieve the 20 pCi/m²s standard. Similar calculations for the sideslopes indicate that at least 76 cm (2.5 ft) of radon barrier is required over that portion of the disposal cell where the UC tailings material will be stabilized. However, to prevent placement of higher-contaminated UC tailings (Ra-226 = 135 pCi/g) directly beneath the radon barrier, the UC tailings were specified to be a minimum distance of 10 ft (3 m) (measured horizontally) away from the edges of the sideslope. Changing the ambient radon concentration in the calculation from 1.5 to 0.5 pCi/L, as noted in Section 6.3.7, did not significantly alter the required cover thickness.

A detailed sensitivity analysis was not conducted for the Burro Canyon radon barrier design in accordance with TAD procedures (DOE, 1989a). The 51-cm radon barrier thickness calculated for the "average + SEM" condition is less than the 61-cm (24-in) barrier that will be constructed; therefore, the design of the disposal cell provides reasonable assurance of compliance with EPA standards. In addition, a sensitivity analysis for the sideslopes is not required because the UC tailings will be placed a minimum distance of 10 ft (3 m) (measured horizontally) away from the edges of the sideslope.

6.5 SITE CLEANUP

Extensive field sampling and radiological surveys were conducted by several investigators to determine the extent and degree of contamination at the Slick Rock sites. Figure 6.1 shows the distribution of contaminated materials.

6.5.1 Radiological site characterization

Details of site characterization data are presented in Calculation 11-212-01-01 in Attachment 1. Measurements of background radioactivity near the Slick Rock sites and measurements of existing radiological site conditions are summarized in Table 6.1.

Table 6.1 Background radioactivity and radiological conditions at the Slick Rock sites

Parameter	Background	NC site	UC site
Gamma exposure rate ($\mu\text{R/hr}$) ^a	13	160	63
Radon-222 (pCi/L)	0.5	4.1	1.4
Radon Flux (pCi/m ² s)	NA	240	70
Radium-226 (pCi/g) ^b	1.4	345	99

^a $\mu\text{R/hr}$ = Microrentgen per hr.

^bVolume-weighted average.

NA - Not applicable.

Approximately 621,000 yd³ (475,000 m³) of contaminated materials cover 69 ac (28 ha) at the Slick Rock processing sites. This excludes the contaminated soil thinly dispersed over 17 ac (7 ha) in the floodplain area across the Dolores River from the UC sites where supplemental standards will be applied.

Additional areas of contamination outside the designated UC and NC sites were determined to be uranium ore deposits which will not be remediated (Attachment 1, Calculation 11-270-01-00).

Estimated design volumes for the various major contaminated materials are presented in Table 1.1 of Section 1.0. Depths of contamination range from less than 0.5 ft (0.2 m) for windblown areas east of the Dolores River in Area 2 to greater than 30 to 50 ft (9 to 15 m) at the NC and UC tailings piles, respectively. The Ra-226 soil concentration at the NC and UC sites ranges from 1 to 8903 pCi/g, with a volume-weighted average of 345 pCi/g for the NC site materials, 135 pCi/g for the UC site tailings, and 35 pCi/g for the UC offpile materials.

6.5.2 Standards for cleanup

The DOE is committed to removing contaminated materials and placing them in an engineered, off-site disposal cell to meet all EPA standards in 40 CFR 192. Applying the supplemental standard provisions of 40 CFR 192 appropriate to vicinity properties will exclude the floodplain area across the Dolores River from the UC site from the remedial action. An appropriate application will be developed and submitted for NRC concurrence. The application will be based on the following conditions: limited long-term health impacts, presented by the low-level Ra-226 contamination dispersed over an estimated 17 ac with an average concentration of 7.4 ± 1.4 pCi/g; human habitation of the area is unlikely because access to the site is limited by the river on one side and steep cliffs on the other; remedial action would be very costly due to necessary construction of a temporary bridge across the Dolores River; and long-term environmental harm from remedial action is probable if scarce riparian habitat is destroyed.

All disturbed areas on the processing site and vicinity properties will be restored to grade for adequate control of surface drainage. No contaminated material or buildings are now planned to be released for unrestricted use; decontamination would be achieved to levels that meet EPA standards, NRC limits, and guidelines and requirements of the *UMTRA Project Environmental, Health, and Safety Plan* (DOE, 1989b).

6.5.3 Verification of cleanup

Excavation control monitoring will be conducted during remedial action to ensure that the 5 pCi/g and 15 pCi/g above background Ra-226 design standards are met for surface and subsurface soils. Verification sampling will prevent both inadequate under-excavation and costly over-excavation. The verification survey will provide reasonable assurance of compliance with the standards.

Thorium-230 (Th-230) will be excavated in accordance with the NRC-approved generic protocol for Th-230 cleanup and verification at UMTRA Project sites. This document is available at the UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

The DOE and the TAC will conduct independent radiological surveillances and health/safety audits during remedial action to ensure that all activities are performed to meet Federal, state, and local standards and guidelines. QC and QA requirements and procedures are in place to ensure that adequate cleanup and subsequent verification are properly implemented and documented (DOE, 1990).

Final verification surveys will document average Ra-226 concentrations on all 1000-ft (100-m²) areas remediated. Nine-plug, composite-surface soil samples will be collected for each 1000-ft (100-m²) area and analyzed by gamma

spectroscopy or other analytical methods approved by the UMTRA Project Office to verify compliance with EPA standards.

In addition, a nine-point composite gamma measurement technique may be used in windblown contaminated areas. This hand-held verification protocol will be site-specific and must be approved by the DOE UMTRA Project Office. The RTRAK mobile detection unit may be used to verify contaminated areas that are too large to sample by hand methods.

Verification sampling for bulk Th-230 will be performed in accordance with NRC-approved generic protocol for Th-230 cleanup and verification at UMTRA Project sites.

6.6 SUMMARY AND CONCLUSION

The DOE is committed to cleaning up the Slick Rock sites in accordance with EPA standards, NRC guidelines, and UMTRA Project health and safety requirements. The disposal cell and radon barrier design will reduce the surface radon flux to levels below the EPA standards defined in 40 CFR 192.02(b). Appropriate supplemental standards will be developed that will exclude the floodplain area across the river from the UC site from remedial action. These supplemental standards will be submitted for NRC approval. Data were collected, verified, and analyzed to provide a reasonable preliminary design; subsequent refinements of the final design will ensure the fulfillment of DOE's commitment.

7.0 LIST OF CONTRIBUTORS

The following individuals contributed to the preparation of this RAP.

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