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United States Department of Energy

Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site At Gunnison, Colorado

Attachment 4, Water Resources Protection Strategy

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Uranium Mill Tailings Remedial Action Project

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ATTACHMENT 4

WATER RESOURCES PROTECTION STRATEGY

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TABLE OF CONTENTS

Section . . . Page

1.0 WATER RESOURCES PROTECTION STRATEGY SUMMARY . . . 1

2.0 CONCEPTUAL DESIGN CONSIDERATIONS AND FEATURES FOR WATER RESOURCES PROTECTION . . . 5
  2.1 Design considerations . . . 5
    2.1.1 Climate and infiltration . . . 5
    2.1.2 Surface drainage . . . 5
    2.1.3 Subsurface drainage . . . 7
    2.1.4 Disposal cell longevity . . . 7
  2.2 Design features . . . 7
    2.2.1 Disposal cell cover components . . . 8
    2.2.2 Transient drainage and control of construction water . . . 10
    2.2.3 Disposal cell longevity . . . 10

3.0 DISPOSAL AND CONTROL OF RADIOACTIVE MATERIALS AND NONRADIOACTIVE MATERIALS CONTAMINANTS . . . 11
  3.1 Groundwater protection standard . . . 11
    3.1.1 Hazardous constituents . . . 11
    3.1.2 Proposed concentration limits . . . 12
    3.1.3 Point of compliance . . . 14
  3.2 Performance assessment . . . 14
    3.2.1 Transmission of tailings seepage in the unsaturated zone . . . 15
    3.2.2 Acid neutralization and geochemical attenuation . . . 16
  3.3 Closure performance assessment . . . 19
  3.4 Groundwater monitoring program . . . 19
  3.5 Corrective action plan . . . 21

4.0 CLEANUP AND CONTROL OF EXISTING CONTAMINATION . . . 23

REFERENCES . . . 25

LIST OF FIGURES

Figure Page

2.1 Diagrammatic cross sections of the proposed disposal cell at the Gunnison disposal site, Colorado 6
2.2 Cross sections of the disposal cell and cover at the disposal site near Gunnison, Colorado 9

3.1 Plan view of disposal cell, point of compliance, and groundwater monitoring network at the Gunnison disposal site 20

LIST OF TABLES

Table Page

3.1 Proposed concentration limits for the disposal site near Gunnison, Colorado 13

1.0 WATER RESOURCES PROTECTION STRATEGY SUMMARY

To achieve compliance with the proposed U.S. Environmental Protection Agency (EPA) groundwater protection standards (Subpart A of 40 CFR 192), the U.S. Department of Energy (DOE) proposes to meet background concentrations or the EPA maximum concentration limits (MCLs) for hazardous constituents in groundwater in the uppermost aquifer (lower Tertiary gravel aquifer) at the point of compliance (POC) at the Gunnison Uranium Mill Tailings Remedial Action (UMTRA) Project disposal site near Gunnison, Colorado (DOE, 1989). 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 Gunnison disposal site follows.

- o The disposal option proposed for the Gunnison uranium processing site involves consolidation of the uranium tailings and associated contaminated materials. These materials will be placed in a partially below-grade disposal cell designed to reduce radon emanation, resist degradation, minimize infiltration, and withstand differential settlement.

- o Several design features were incorporated into the disposal cell to minimize moisture drainage. A multiple-component cover has been included. Riprap will prevent erosion of the disposal cell. Coarse sand to fine gravel bedding will prevent material displacement and protect the underlying frost protection layer from erosion. A sand, gravel, and cobble layer will prevent the vertical movement of water (capillary break). The radon barrier will limit the flux of radon from the cell to acceptable concentrations. The tailings will be placed near optimum moisture content to minimize transient drainage. The disposal cell foundation and the location of the site have been optimized to utilize favorable geochemical conditions and hydrogeologic conditions of the site. The disposal cell has been designed to account for the following factors: the importance of climate on the rate of infiltration through the cover of the disposal cell; the effects of transient drainage on subsurface drainage into foundation materials; the relation of transient drainage to the thickness of foundation materials required to geochemically attenuate hazardous constituents in the tailings seepage; retardation of hazardous constituents in tailings seepage in the unsaturated zone; and the storage of soil moisture in the unsaturated zone.

- o To achieve compliance with the proposed EPA groundwater protection standards at the disposal site, the DOE proposes to meet background concentrations or MCLs for the designated hazardous constituents in the uppermost aquifer at the POC. The POC is the downgradient edge of the disposal cell. The lower Tertiary gravel aquifer is the uppermost aquifer at the Gunnison disposal site.

- o Selection of hazardous constituents (40 CFR 192.02, Table 1, Appendix I, and Appendix IX, 40 CFR 264) is based upon hydrogeologic characterization at the processing and disposal sites. The hazardous constituents at the Gunnison site resulted from the uranium processing operations and will be present in materials stabilized at the disposal site. These constituents were identified from descriptions of the uranium recovery process, characterization of the contaminated materials, and evaluation of groundwater quality data. Based upon lysimeter pore fluid test analyses data, the following 11 hazardous constituents with quantified MCLs exceeded the laboratory method detection limits: arsenic, cadmium, chromium, net gross alpha (gross alpha minus uranium), lead, molybdenum, nitrate, radium-226 and -228, selenium, silver, and uranium. Nine additional potentially hazardous constituents that exceeded the laboratory method detection limits are antimony, beryllium, cobalt, copper, nickel, thallium, tin, vanadium, and zinc.

- Concentrations of nine hazardous constituents exceeded the MCLs in tailings pore water. These hazardous constituents are arsenic, cadmium, chromium, lead, molybdenum, net gross alpha, radium-226 and -228, selenium, and uranium. Nine hazardous constituents listed in Appendix I of 40 CFR 192 or Appendix IX of 40 CFR 264 exceeded the statistical maximum background groundwater concentration. These constituents are antimony, beryllium, cobalt, copper, nickel, thallium, tin, vanadium, and zinc.

- Elements of hazardous compounds (40 CFR 192.02, Appendix I) were also examined. The four elements and their respective hazardous compounds are the following: (1) aluminum as aluminum phosphide; (2) ammonium as a salt of vanadic acid; (3) fluoride as carbon oxyfluoride; and (4) strontium as strontium sulfide. None of these four compounds would exist in solution. Therefore, these hazardous compounds and their respective elements are not considered to be hazardous constituents that may occur at the disposal site.

- The proposed concentration limits for the designated hazardous constituents were selected based upon the MCLs or the statistical maximum background concentrations (for constituents without MCLs) in groundwater in the uppermost aquifer at the disposal site. The statistical maximum is the 98 percent confidence maximum for constituents with normal, lognormal, and nonparametric distributions. In some cases, based upon the distribution, statistics were not appropriate and the maximum observed concentration or the method detection limit was chosen (see Attachment 3, Section 3.1.5). The proposed concentration limits for arsenic, cadmium, chromium, lead, molybdenum, net gross alpha, radium-226 and -228, selenium, and uranium will be the EPA MCLs. Proposed concentration limits for antimony, beryllium, cobalt, copper, nickel, thallium, tin, vanadium, and zinc will be the statistical maximum background groundwater concentration of these constituents.

- The results of the geochemical investigations indicate that the hazardous constituents antimony, beryllium, cadmium, chromium, cobalt, copper, nickel, lead, vanadium, zinc, and oxidized species of arsenic, molybdenum, selenium, and uranium in the Gunnison tailings pore fluid would be removed below the concentration limits (MCL or background groundwater concentrations at the disposal site) due to neutralization of the tailings leachate and subsequent adsorption. Dissolved lead and thallium are also likely to be adsorbed onto mineral surfaces in the upper Tertiary gravels and underlying Lahar mudflow. Net gross alpha and radium activity is expected to be controlled by minerals within the Tertiary gravels and should be within the range of background. Tin is expected to be insoluble in groundwater at the disposal site; the dominant dissolved species of tin in the tailings pore water is expected to be Sn^{+4}, which would hydrolyze to highly insoluble $Sn(OH)_4$.

- The POC at the Gunnison disposal site will be downgradient along the west, east, and north edge of the disposal cell in the uppermost aquifer, which is the lower Tertiary gravel aquifer.

- The DOE will meet concentration limits at the POC in the uppermost aquifer because:

  1) The disposal cell design minimizes infiltration through the cover; the tailings will be placed at a moisture content that produces minimal transient drainage; and the use of water for construction and dust suppression will be controlled. As a result, very little seepage is transmitted through the unsaturated zone during the design life of the disposal cell.

  2) Geochemical characteristics of the foundation soils and rock are favorable for attenuating hazardous constituents in tailings seepage from the base of the disposal cell. Hazardous constituents that exceed the MCLs or statistical maximum background concentrations are precipitated or adsorbed in the unsaturated zone before they reach the water table in the uppermost aquifer.

- The DOE has assessed the performance of the disposal cell in conjunction with the hydrogeologic system and has shown that the disposal cell will minimize and control releases of hazardous constituents to groundwater and surface water and radon emanations to the atmosphere to the extent necessary to protect human health and the environment. Natural, stable materials have been proposed for use in construction of the Gunnison disposal cell so that long-term performance is ensured. The final design consideration is to comply with the longevity requirement in 40 CFR 192.

- A groundwater monitoring program will be implemented during and after remediation to demonstrate that the performance of the disposal unit is in accordance with the design requirements, and to ensure compliance of the disposal site with the EPA groundwater protection standards. Groundwater in the uppermost aquifer will be monitored downgradient from the disposal cell at the POC, using existing DOE monitor wells where applicable and installing new monitor wells as necessary. Background groundwater quality monitoring will continue upgradient from the disposal cell. Compliance wells will be sampled twice during the construction period, quarterly during the first year following completion of the remedial action, semiannually during years two through five, and annually thereafter until the end of the performance monitoring period. The constituents to be monitored will include designated hazardous constituents with concentration limits established during site characterization. Potential excursions for the designated hazardous constituents will be based on the exceedance of the MCLs or statistical maximums in background groundwater characterizing the Gunnison disposal site.

- Demonstration of cleanup and control of existing processing-related groundwater contamination will be addressed under a separate DOE 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 site, should it be required, because the tailings will be relocated to a remote disposal site.

2.0 CONCEPTUAL DESIGN CONSIDERATIONS AND FEATURES FOR WATER RESOURCES PROTECTION

2.1 DESIGN CONSIDERATIONS

2.1.1 Climate and infiltration

Climate is an important design consideration. It influences the quantity of water available to percolate through the cover of the disposal cell and through stabilized residual radioactive materials, and it has a potential effect on the migration of hazardous constituents to groundwater.

The climate in the vicinity of the Gunnison site is semiarid. The average annual precipitation is 11 inches, with half of the precipitation in the form of winter snow and half as thundershowers. The wettest months are July and August, with an average of 1.7 inches per month. November and December are the driest months, with about 0.7 inch per month. The annual normal temperature is 37.7°F. Average daily winter temperatures are usually about 10°F, with a 31°F diurnal range, while summer temperatures average 60°F and have a 40° diurnal range. Prevailing winds are most frequently from the west. Adjusted evapotranspiration at the Gunnison site is approximately 10.5 inches per year, over 90 percent of the average annual precipitation.

The high rate of evapotranspiration at the Gunnison disposal site is advantageous for limiting deep percolation of precipitation through the proposed disposal cell. To minimize infiltration, it is necessary to optimize soil thickness and soil texture, and to minimize the permeability of the underlying infiltration barrier. Cover performance is discussed in more detail in Section 2.2.

2.1.2 Surface drainage

The relation of surface topography to disposal cell location and final grading should consider the ability of the disposal cell to divert surface flow from around the disposal cell and limit the quantity of water available for infiltration by shedding surface flow from the disposal cell.

Topographically, the disposal site lies on a southward-sloping plain dissected by erosion features that include two narrow to moderately broad gullies. The gullies trend to the west and southeast of the site, respectively, as shown on Figure 2.1. The sloping plain on which the disposal cell will be placed is formed on extensive gravel soils.

Surface runoff from the drainage area north of the site will be diverted laterally away from the disposal cell by a permanent interceptor ditch north of the disposal site. The ditch will be constructed to divert surface runoff partly through the east branch and partly through the west branch to riprap-lined outlets, then to the existing ground. The natural surface slope and the final grade

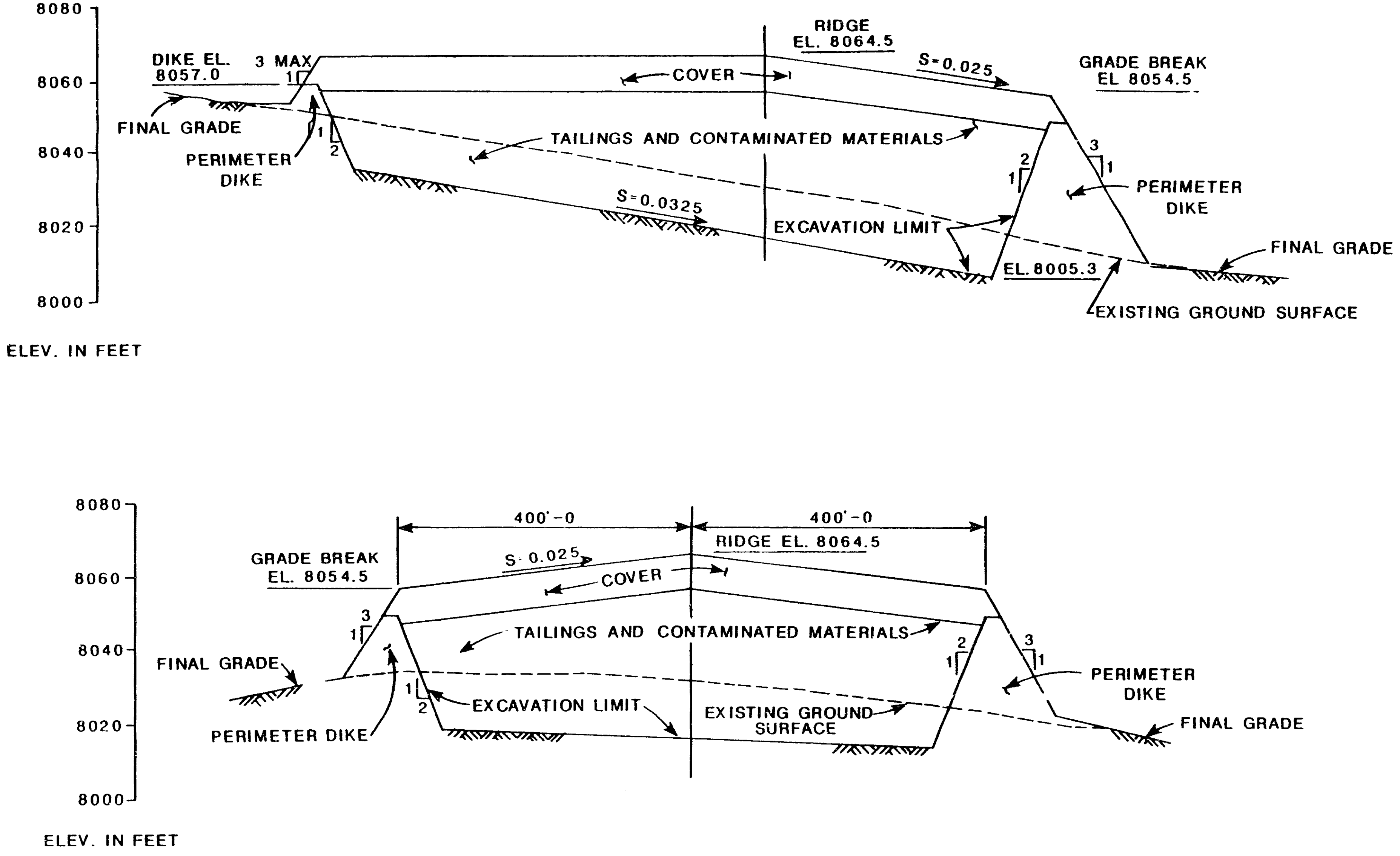

FIGURE 2.1
DIAGRAMMATIC CROSS SECTIONS OF THE PROPOSED DISPOSAL CELL
AT THE GUNNISON DISPOSAL SITE, COLORADO

of the disposal site will facilitate drainage of surface waters around the disposal cell rather than into it.

2.1.3 Subsurface drainage

The ability of the disposal cell foundation to accept transient drainage of excess moisture from the tailings without adversely impacting groundwater or surface water resources is an important design consideration.

The saturated and unsaturated hydraulic conductivity characteristics of the subsoils beneath the proposed disposal cell have been evaluated. The foundation soils are clayey to sandy gravel, and are capable of accepting tailings drainage without creating a perched saturated surface in the foundation soils. The unsaturated zone is approximately 100 feet thick below the proposed disposal cell. Hydraulic conductivities for the tailings and gravel in the unsaturated zone are approximately 7.1×10^{-3} ft/day (2.5×10^{-6} cm/s) and 1.1 ft/day (3.9×10^{-4} cm/s), respectively (Calculation No. GUN-03-91-02-04-01, Appendix C of Attachment 3).

The amount of transient drainage that can be allowed is dependent upon the geochemical attenuation capabilities of the subsoils, the ability of the unsaturated zone to accept transient drainage as storage, and the capability of the lower Tertiary gravel aquifer to dilute and disperse concentrations below the proposed concentration limits. Sections 2.2.2, 3.2.1, and 3.2.2 discuss subsurface drainage in detail as it relates to the overall performance of the disposal cell.

2.1.4 Disposal cell longevity

The EPA groundwater protection standards require that the disposal cell be designed to stabilize the contaminated material and protect the environment for 1000 years where reasonably achievable, and in any case for at least 200 years.

2.2 DESIGN FEATURES

This section describes the principal design features of the proposed disposal cell. The design features will ensure compliance with the EPA groundwater protection standards. This section will also demonstrate that the design features 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 cover approximately 29 acres. The cell will rise to a maximum height of 50 feet above the surrounding ground surface. The top of the disposal cell will slope at 2.5 percent, and the sides of the cell will slope at 33 percent (see Figure 2.1).

2.2.1 Disposal cell cover components

The disposal cell cover will have a rock riprap surface layer and additional components below the rock. Figure 2.2 is a diagrammatic cross section through the disposal cell. Figures 3.15 and 3.16 of Attachment 3 are hydrostratigraphic cross sections of the disposal cell at the Gunnison disposal site.

From top to bottom, the disposal cell top slope cover consists of the following components:

- o Rock riprap (0.5 foot thick)
- o Coarse sand to fine gravel bedding (0.5 foot thick)
- o Select fill frost protection (six feet, one inch thick)
- o Sand, gravel, cobbles capillary break (0.5 foot thick)
- o Radon barrier (1.5 feet thick)

The characteristics and purpose for including each of these cover components are discussed in more detail as follows:

Riprap

The primary purpose of the rock riprap will be to prevent erosion of the disposal cell by precipitation and surface water runoff.

Coarse sand to fine gravel bedding

Beneath the riprap will be 0.5 foot of coarse sand to fine gravel bedding. The bedding layer prevents displacement of the large diameter rock on the surface layer and helps protect the underlying frost protection layer (fine-grained material) from erosion. An additional function of the bedding layer is as drain that allows lateral movement of water across the pile.

Select fill frost protection

Underlying the bedding layer will be approximately six feet of fine-grained material. The purpose of this layer is to prevent the radon barrier from freezing. The estimated maximum frost depth for the Gunnison disposal site is around 7.5 feet (Attachment 1, Calculation No. GUN-643-02-02). This fill layer will have an estimated saturated hydraulic conductivity ranging from 2.7 x 10^{-6} to 2.7 x 10^{-7} cm/s (Attachment 1, Calculation No. GUN-680-01-01).

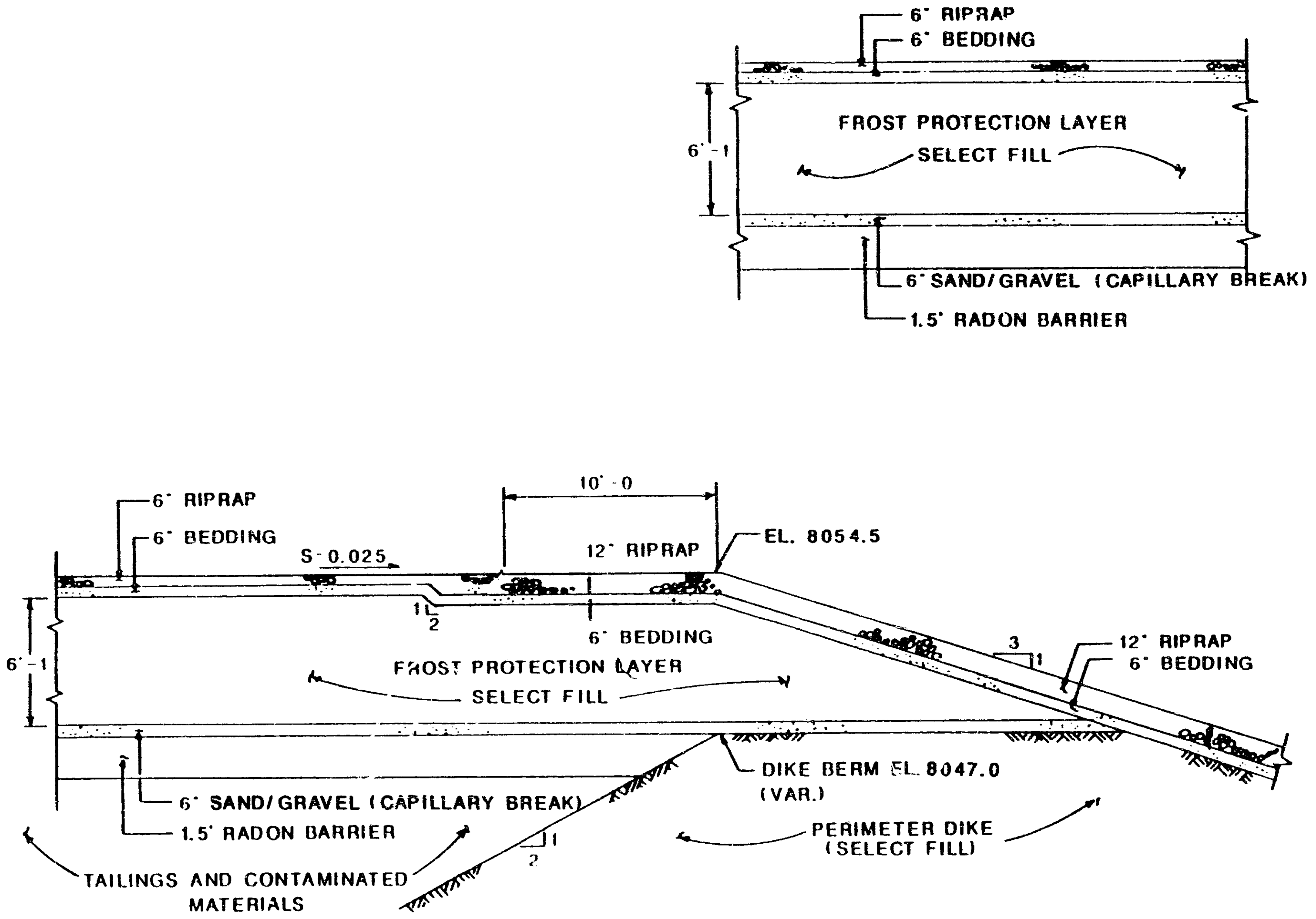

FIGURE 2.2

CROSS SECTIONS OF THE DISPOSAL CELL AND COVER AT THE DISPOSAL SITE NEAR GUNNISON, COLORADO

Sand, gravel, cobble capillary break

This layer directly beneath the frost protection layer is included primarily to prevent the vertical movement of water (capillary break). The saturated hydraulic conductivity of this layer will be at least one or two orders of magnitude greater than permeability of the radon barrier.

Radon barrier

The radon barrier will be 1.5 feet thick and will be composed primarily of a sandy clay (Attachment 1, Calculation Nos. GUN-680-01-01 and GUN-643-01-01). The primary purpose of the radon barrier will be to limit the flux of radon from the contaminated materials within the cell to acceptable concentrations. The radon barrier will be amended with five percent bentonite, and the resulting saturated hydraulic conductivity for the layer will be approximately 1 x 10^{-8} cm/s. Thus, the low saturated hydraulic conductivity of the material will also help to inhibit infiltration of surface water through the contaminated material.

2.2.2 Transient drainage and control of construction water

The tailings will be placed at around their optimum moisture content. An analysis of drainage and contaminant transport from the tailings after placement and compaction was performed (Calculation No. GUN-03-91-02-04-01, Appendix C of Attachment 3). Results of the analysis show that transient drainage of moisture will not transport hazardous or radiological contaminants to the uppermost aquifer within 1000 years. In addition, transient drainage of tailings moisture will not cause a wetting front (pulse) to propagate through the unsaturated zone between the tailings and potentiometric surface under reasonable case conditions.

Construction water for compaction and dust control will be minimized so that moisture contents in the disposal cell materials will not cause an increase in the predicted flux of transient drainage. Moisture will only be added to contaminated materials for environmental dust control requirements.

2.2.3 Disposal cell longevity

Natural, stable materials have been proposed for use in construction of the Gunnison disposal cell to ensure long-term performance. Materials for the rock erosion protection layer have been selected, based on durability, suitability, and size, that will 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.

3.0 DISPOSAL AND CONTROL OF RADIOACTIVE MATERIALS AND NONRADIOACTIVE MATERIALS CONTAMINANTS

3.1 GROUNDWATER PROTECTION STANDARD

The proposed disposal cell is designed to control radioactive materials and nonradioactive contaminants in conformance with groundwater protection standards as required by the proposed EPA standards in 40 CFR 192.02(a)(3). The DOE proposes to meet background concentrations or EPA MCLs for designated hazardous constituents in groundwater in the uppermost aquifer at the POC at the Gunnison disposal site. The lower Tertiary gravel is considered to be the uppermost aquifer beneath and hydraulically downgradient from the disposal site.

Groundwater occurs in the lower portion of the Tertiary volcaniclastic stratum at a depth of 34 to 69 feet beneath the present land surface of the Gunnison disposal site. This unit overlies the lower Tertiary gravel beneath the disposal cell. However, it is not considered to be the uppermost aquifer because of the unit's low hydraulic conductivity and lack of ability to effectively transmit water (see Section 3.2.3 of Attachment 3).

The EPA groundwater protection standard consists of three components: (1) a list of designated hazardous constituents; (2) a corresponding list of proposed concentration limits for the constituents; and (3) a POC. These three main components are discussed below.

3.1.1 Hazardous constituents

Hazardous constituents at the 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 discussed in Attachment 3.

Hazardous constituents are defined according to two criteria: (1) they must be present in, or reasonably expected to be present in or derived from, the residual radioactive material to be stabilized at the disposal site; and (2) they must be constituents listed in Appendix I of 40 CFR 192 or in Appendix IX of 40 CFR 264.

The processing site was screened for a total of 117 organic compounds from the priority pollutant list in February 1988. These 117 compounds can be delineated into separate organic compound categories. The categories and the number of compounds in each category are: volatile compounds (31); base/neutral compounds (46); acid compounds (11); pesticides and polychlorinated biphenyls (25); and additional compounds (four). No organic priority pollutants were detected in the February 1988 analyses. A trace quantity of methylene chloride was detected in one sample collected from an on-site monitor well and from an analytical duplicate for the same sample. The occurrence of this compound is most likely the result of laboratory contamination, since it was detected in both the monitor well sample and the accompanying duplicate.

The processing site was screened for 35 organic compounds in February 1989. These organic hazardous constituents are listed in Appendix IX of 40 CFR 264 (and therefore in Table 1 and Appendix I of 40 CFR 192 by reference). Groundwater samples were collected from one background monitor well (002), one on-site monitor well (006), and one downgradient monitor well (113). One organic constituent, bis(2-ethylhexyl)phthalate, was detected in all three groundwater samples. In addition, the spike for sample 006 (prepared by the laboratory but not spiked with bis(2-ethylhexyl)phthalate), also had a relatively high concentration of this compound. The compound bis(2-ethylhexyl)phthalate, and phthalate esters in general, are commonly used in the organic chemical industry in plastic manufacturing and production (Verschueren, 1983). The EPA (1982) reports, "Phthalate esters are contaminants in many products commonly found in the laboratory . . . phthalates are commonly used as plasticizers and are easily extracted from plastic materials." Bis(2-ethylhexyl)phthalate is not a hazardous constituent used in uranium processing operations. The occurrence of this compound is most likely the result of laboratory contamination from plastic materials and not an indication of contamination from uranium processing. This conclusion is supported by the 1988 organic analyses; bis(2-ethylhexyl)phthalate was measured below the detection limits in all samples analyzed.

The tailings source term has been characterized, based on water quality data collected from 15 lysimeters installed to the base of the tailings, during 1990 and 1991. Eleven inorganic hazardous constituents with MCLs exceed laboratory method detection limits in the tailings pore fluid samples. These constituents are arsenic, cadmium, chromium, lead, molybdenum, net gross alpha (gross alpha minus uranium), nitrate, radium-226 and -228, selenium, silver, and uranium. Nine additional hazardous constituents included in Appendix I of 40 CFR 192 and Appendix IX of 40 CFR 264 that exceeded the laboratory method detection limits are antimony, beryllium, cobalt, copper, nickel, thallium, tin, vanadium, and zinc.

The four elements in hazardous constituent compounds and their respective hazardous compounds are the following: (1) aluminum as aluminum phosphide; (2) ammonium as a salt of vanadic acid; (3) fluoride as carbon oxyfluoride; and (4) strontium as strontium sulfide. None of these four compounds would exist under geochemical conditions expected of uranium mill tailings. Therefore, these hazardous compounds and their respective elements are not considered as hazardous constituents at the Gunnison disposal site.

3.1.2 Proposed concentration limits

To achieve compliance with the proposed EPA groundwater protection standards at the Gunnison disposal site, the DOE proposes to meet MCLs or background concentrations in groundwater in the uppermost aquifer (lower Tertiary gravel) at the POC for the hazardous constituents designated in Section 3.1.1 and listed in Table 3.1.

Table 3.1 Proposed concentration limits for the disposal site near Gunnison, Colorado[a]

Constituents with MCLs

Hazardous constituent	Source term conc.	Lab. detection limit	MCL	Background[b] median/stat. max.		Proposed conc. limit
Arsenic	19.21[c]	0.01	0.05	0.03[d]	0.04	0.05
Cadmium	2.42[d]	0.001	0.01	0.001[f]	0.001[f]	0.01
Chromium	0.74[d]	0.01	0.05	0.01[f]	0.01[f]	0.05
Lead	0.06	0.01	0.05	0.01[f]	0.01[f]	0.05
Molybdenum	1.33[d]	0.01	0.10	0.01[f]	0.01[f]	0.10
Net gross alpha[e]	5513.78	--	15.0	1.32	3.72	15.
Radium-226 and -228[e]	34.1	0.1	5.0	1.0	1.5	5.0
Selenium	0.23	0.005	0.01	0.005[f]	0.005[f]	0.01
Uranium	4.87[c]	0.003	0.044	0.003[f]	0.004	0.044

Constituents without MCLs

Hazardous constituent	Source term conc.	Lab. detection limit	MCL	Background[b] median/stat. max.		Proposed conc. limit
Antimony	0.02	0.003	None	0.003[f]	0.003[f]	0.003
Beryllium	0.23[d]	0.01	None	0.01[f]	0.01[f]	0.01
Cobalt	19.37[d]	0.05	None	0.05[f]	0.05[f]	0.05
Copper	23.30[d]	0.02	None	0.02[f]	0.02[f]	0.02
Nickel	25.91[d]	0.04	None	0.04[f]	0.04[f]	0.04
Thallium	0.07	0.01	None	0.01[f]	0.01[f]	0.01
Tin	0.01	0.005	None	0.005[f]	0.005[f]	0.005
Vanadium	1.40	0.01	None	0.01[f]	0.01[f]	0.01
Zinc	76.82	0.005	None	0.005[f]	0.006	0.006

[a] All units are mg/l unless otherwise noted.
[b] Disposal site background groundwater statistical maximum.
[c] Lognormal distribution, mean is geometric.
[d] Normal distribution, mean is arithmetic.
[e] Units are pCi/l.
[f] Statistical values are below laboratory detection limits in Table 8.1 of the Technical Approach Document (DOE, 1989).

Statistical maximum concentrations of background groundwater quality data at the disposal site are presented in Table 3.1 to compare the quality of groundwater occurring naturally at the disposal site to the tailings pore fluid. The background groundwater quality data tabulated are the result of statistical maximums calculated for 10 monitor wells completed to various depths within the lower Tertiary gravel aquifer. The proposed concentration limits are based on EPA groundwater protection standards and the statistical maximum background concentrations in groundwater in the lower Tertiary gravel aquifer beneath the site. When the statistical values are below the detection limits, then the proposed statistical maximum background concentrations represent the laboratory detection limits listed in Table 8.1 of the Technical Approach Document (DOE, 1989).

3.1.3 Point of compliance

The POC at the Gunnison disposal site will be the downgradient edge of the disposal cell in the uppermost regional aquifer, which is the lower Tertiary gravel (Figure 5.5 of the Remedial Action Selection Report). Predicted concentrations of hazardous constituents at the POC are discussed in the performance assessment provided in Section 3.2. Future groundwater monitoring plans, including the monitor well network at the POC and the frequency of sampling, are discussed briefly in Section 3.4, and will be presented in detail in the forthcoming long-term surveillance plan (LTSP) for the Gunnison disposal site.

3.2 PERFORMANCE ASSESSMENT

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). To achieve compliance, the DOE proposes to meet MCLs or the statistical maximum for the hazardous constituents (listed in Table 3.1) in background groundwater in the uppermost regional aquifer (lower Tertiary gravel) at the POC.

Of the hazardous constituents that exceed laboratory method detection limits in tailings pore fluids, barium, mercury, and nitrate are below the MCLs and will therefore meet the concentration limits (Calculation No. GUN-04-90-14-07-01, Appendix C of Attachment 3). This performance assessment is concerned with constituents in the tailings pore fluid solution that meet the following criteria:

- o Statistical means or medians exceed the MCLs: arsenic, cadmium, chromium, net gross alpha, lead, molybdenum, radium-226 and -228, selenium, and uranium.
- o Statistical means or medians exceed the statistical maximum for background groundwater quality in the uppermost aquifer at the disposal site: antimony, beryllium, cobalt, copper, nickel, thallium, tin, vanadium, and zinc.

3.2.1 Transmission of tailings seepage in the unsaturated zone

The transmission of tailings seepage through the unsaturated zone to the water table was simulated with WORM (USDA, 1985), a one-dimensional saturated-unsaturated water flow and solute transport model for nonhomogeneous soil profiles (Calculation No. GUN-03-91-02-04-01, Appendix C of Attachment 3). Saturated-unsaturated flow is calculated with the Richard's equation, while solute transport is based on a convection-dispersion solute transport equation. A fully implicit finite element method is used to solve both the water flow and solute transport equations. The simulation of transport of hazardous constituents to the water table is discussed in Section 3.2.2.

Material unsaturated flow properties that were used as input to the model included the initial moisture content distribution, boundary conditions, and unsaturated flow parameters generated from capillary moisture curves by the model RETC (Van Genuchten, 1985). The upper boundary condition to the model was assumed to be a conservative value for the steady state flux through the disposal cell cover, or 1×10^{-7} cm/s. A test value of 1.1×10^{-8} cm/s was calculated for the permeability of the radon barrier amended with five percent bentonite (MK Calculation GUN-680-01-01). Therefore, a 1×10^{-7} cm/s saturated permeability of the radon/infiltration barrier will ensure that the design meets the requirements of the groundwater compliance strategy.

Water flow and solute transport was simulated for two soil profiles, the most representative being a one-dimensional, nonhomogeneous soil profile consisting of (from top to bottom):

- o Sand-slime tailings (1280 cm thick).
- o Clayey foundation gravel (610 cm thick).
- o Volcaniclastic material/Lahar breccia (2250 cm thick).

The steady-state flux boundary (1×10^{-7} cm/s) was imposed on the top of the tailings. This is a very conservative condition, in that steady-state flow (equilibrium conditions) through the cover is assumed to occur throughout the period simulated. The lower boundary of the model is assumed to be the water table.

A plot of moisture content versus depth below the disposal cell was generated from the results of modeling the above-referenced vertical profile (Figure 24, Calculation No. GUN-03-91-02-04-01, Appendix C of Attachment 3). The degree of pore saturation of the tailings was assumed to be 84 percent, the design optimal moisture content. The percent saturation decreases to approximately 68 percent in the foundation gravels (1280 cm and 1890 cm), between the base of the tailings and the top of the Lahar breccia. The vadose zone is sufficiently dry that lateral movement of water will be limited and did not require three-dimensional modeling. As a result, the potential impact of hazardous constituents along the unsaturated flow path in the upper gravel is minimal. The percent saturation increases to approximately 90 percent at the contact between the foundation gravels and the Lahar breccia, and remains relatively constant. The hydraulic conductivity of the Lahar breccia is very low (2.5 x 10^{-7} cm/s or less). Thus, solute transport through this layer was not considered.

Very little seepage is transmitted through the unsaturated zone during the design life of the disposal cell. The tailings will be placed at a low moisture content that produces minimal transient drainage. The results of the one-dimensional vertical transport simulations demonstrate that disposal cell design minimizes infiltration through the cover. During construction, water used for dust suppression and other operational activities will be controlled to maintain the low moisture content of the tailings for placement in the disposal cell.

3.2.2 Acid neutralization and geochemical attenuation

Section 3.2.6 of Attachment 3 discusses in detail the geochemical conditions of the foundation soils at the Gunnison disposal site. Geochemical investigations have been conducted to predict geochemical attenuation at the Gunnison disposal site. The results of these investigations are summarized in this section.

Hazardous constituents in solution as cations (i.e., aluminum, cadmium, cobalt, iron, nickel, vanadium, and zinc) precipitate due to acid neutralization. These characteristics indicate that some of the hazardous constituents present in the tailings pore fluid would be removed due to neutralization in the unsaturated zone within the upper gravel. Laboratory neutralization tests were conducted in order to verify this observation.

Tailings pore fluid samples, collected from lysimeters at the Gunnison processing site, were combined and subjected to geochemical testing by neutralization. Calcium carbonate was used a neutralizing agent because there is natural calcite ($CaCO_3$) in the Tertiary gravels that will make up the foundation of the cell. A comparison of the composition of the pore fluid and the neutralized solution indicated that the removal efficiency for nearly all of the hazardous constituents is in excess of 98 percent. The neutralized tailings solution is expected to be unsaturated with respect to all of the hazardous constituents.

The geochemical model PHREEQE (Parkhurst et al., 1980) was used to assess the mechanism for attenuation of the hazardous constituents due to neutralization. The PHREEQE modeling results indicate that when the test solution is equilibrated with calcite, the following hazardous constituents will precipitate: aluminum, cadmium, copper, nickel, lead, strontium, zinc, and oxidized species of arsenic, molybdenum, selenium, and uranium. However, the concentrations of these constituents in the experimentally neutralized test fluid are lower than the model-predicted thermodynamic solubility limits under the geochemical conditions of the pore water. Therefore, it is likely that the hazardous constituents were partially removed by the iron and aluminum hydroxides that precipitated during neutralization.

Following the neutralization tests, batch adsorption testing was conducted by running the neutralized solution through the two gravel units that will make up the disposal cell foundation, the upper and undifferentiated gravels. The batch test data show that the hazardous constituents in the neutralized test fluid were further attenuated by the composite samples. It is predicted that this attenuation is primarily due to adsorption onto mineral surfaces.

The transport of hazardous constituents through the unsaturated zone to the water table was also simulated using the WORM computer code (an updated version of SUMATRA-I), which simulates water flow and solute transport in a one-dimensional, heterogeneous sediment profile. Input to the model included a range of dispersivities, and the porosity, bulk density, and distribution coefficient for each material. Modeling efforts focused primarily on molybdenum and uranium, as they tend to be the least adsorbed. Based on an assessment of the simulation results, uranium and molybdenum will not exceed their respective MCLs at the water table within a 1000-year period. Retardation by adsorption along the flow path to the water table will be the mechanism of attenuation. Other hazardous constituents, including antimony, arsenic, beryllium, cadmium, cobalt, copper, nickel, selenium, vanadium, and zinc, also will not reach the water table, as a result of precipitation during neutralization.

Summary of hazardous constituent compliance

Favorable geochemical conditions are present at the disposal site for the attenuation of hazardous constituents present in the tailings pore fluid. The results of the geochemical investigations indicate the hazardous constituents antimony, beryllium, cadmium, chromium, cobalt, copper, nickel, lead, vanadium, zinc, and oxidized species of arsenic, molybdenum, selenium, and uranium in the Gunnison tailings pore fluid would be removed below the concentration limits (MCL or background groundwater concentrations at the disposal site) due to neutralization and adsorption reactions. The acid neutralization capacity and the batch test data using the neutralized test fluid indicate that the removal would take place within less than five feet of the bottom of the disposal cell.

The constituents lead, net gross alpha, and radium-226 and -228 in the tailings pore fluid exceed the regulated concentration limits. The tailings pore fluid contained the hazardous constituents antimony, beryllium, cadmium, chromium, cobalt, copper, nickel, lead, vanadium, zinc, and oxidized species of arsenic, molybdenum, selenium, and uranium. It is expected that lead, net gross alpha, radium-226 and -228, thallium, and tin would not impact the groundwater at the disposal site for the following reasons.

- The median concentration of lead in the Gunnison tailings pore fluid is 0.06 mg/l, which slightly exceeds the EPA UMTRA groundwater MCL of 0.05 mg/l. In the acidic Gunnison tailings pore fluid, the dissolved ionic species of lead would be Pb^{2+}, which is likely to be adsorbed onto the clay minerals or the organic carbon present in the upper Tertiary gravels. Sulfate is the dominant anion in the Gunnison tailings pore fluid. Lead sulfate minerals (anglesite and plumbojarosite) are insoluble and lead would precipitate. In addition, the mobility of lead in natural water is known to be restricted by adsorption onto iron hydroxides (Rose et al., 1979).

- The net gross alpha activity is calculated by subtracting the uranium and radon activities from the measured gross alpha activity. Because gross alpha is measured from a precipitate formed by evaporation of the solution, the radon has been removed from the sample. In the Gunnison tailings pore fluid, the initial net gross alpha is negative, which indicates that the alpha activity expected from the uranium concentration is greater than the measured alpha activity. Alpha activity is added by both the upper and undifferentiated Tertiary gravels (Appendix A of Attachment 3, Tables 3.33 and 3.34). This was confirmed by leach tests on these materials (Calculation No. GUN-06-92-13-05-02, Appendix C of Attachment 3). Therefore, the net gross alpha activity in the tailings pore fluid should be controlled by the minerals within the gravels and should be within the range of background.

- Radium occurs as the Ra^{2+} ion in the acidic tailings pore fluid. The radium MCL is 5.0 pCi/l. Neutralization of the tailings pore fluids and the contaminant precipitation of gypsum ($CaSO_4 \cdot 2H_2O$) will remove over 98 percent of the radium. The batch tests indicate that the upper gravel contributes radium to solution, but that the undifferentiated gravel removes about 73 percent of the radium from solution. Radium concentrations of the fluids that traverse the vadose zone should be within the range of background.

- The median concentration of thallium in the Gunnison tailings pore fluid is 0.068 mg/l, and its proposed background groundwater concentration at the disposal site is 0.05 mg/l. Thallium occurs in natural water as Tl^+ and as Tl^{3+} in extremely oxidizing conditions (Wedepohl, 1978). Thallium occurs as large electropositive ions; therefore, it is strongly adsorbed by clay minerals.

- The median concentration of tin in the tailings pore fluid is 0.013 mg/l, which is above the proposed background groundwater concentration (0.005 mg/l) at the disposal site. The dominant dissolved species of tin in the tailings pore fluid is expected to be Sn^{4+}, which would hydrolyze to highly insoluble $Sn(OH)_4$. The extremely low solubility of tin is reflected in the low concentration in natural water (Wedepohl, 1978).

3.3 CLOSURE PERFORMANCE ASSESSMENT

The DOE has demonstrated that the proposed remedial action plan at the disposal site will comply with Subpart A (40 CFR 192) of the proposed EPA groundwater protection standards by meeting MCLs or background concentrations at the POC. The DOE has assessed the performance of the designed disposal cell at the Gunnison disposal site in conjunction with the hydrogeologic system, and has shown that the disposal cell will negate the release of hazardous constituents to groundwater and surface water and radon emanations to the atmosphere to the extent necessary to protect human health and the environment (40 CFR 192.02).

Natural, stable materials have been proposed for use in the construction of the disposal cell so that long-term performance is ensured (see Section 2.2.1). The DOE has also demonstrated that the design features necessary for compliance with the groundwater protection standards minimize the need for further maintenance of the disposal site.

3.4 GROUNDWATER MONITORING PROGRAM

Pursuant to 40 CFR 192.02(a)(4)(b), this section addresses a groundwater monitoring program to be carried out during and after the remedial action period, which will be adequate to demonstrate that initial performance of the disposal cell is in accordance with the design requirements. A detailed groundwater monitoring program will be provided in the LTSP for the Gunnison disposal site.

A program to monitor groundwater in the uppermost aquifer (lower Tertiary gravels) will consist of analyzing groundwater samples collected from a series of monitor wells:

- Six POC monitor wells installed on the western, eastern, and southern downgradient edges of the disposal cell.
- Existing background DOE monitor wells upgradient of the disposal cell.
- Existing DOE monitor wells downgradient from the proposed POC.

The proposed monitor well network is shown in Figure 3.1.

Performance monitoring frequency will be outlined in the LTSP for the Gunnison disposal site. A typical monitoring schedule follows: compliance monitor wells will be sampled twice during the construction period, quarterly during the first year following completion of remedial action, semiannually during years two through five, and annually thereafter until the end of the performance monitoring period. The constituents to be monitored include designated hazardous constituents listed on Table 3.1.

The definition of an excursion for the designated hazardous constituents at the disposal site will be based on the exceedance of the MCLs or statistical maximums in background groundwater characterizing the Gunnison disposal site. Potential excursions will be discussed in detail in the LTSP. Natural variability is associated with proposed concentration limits for the designated hazardous constituents at the disposal site. This

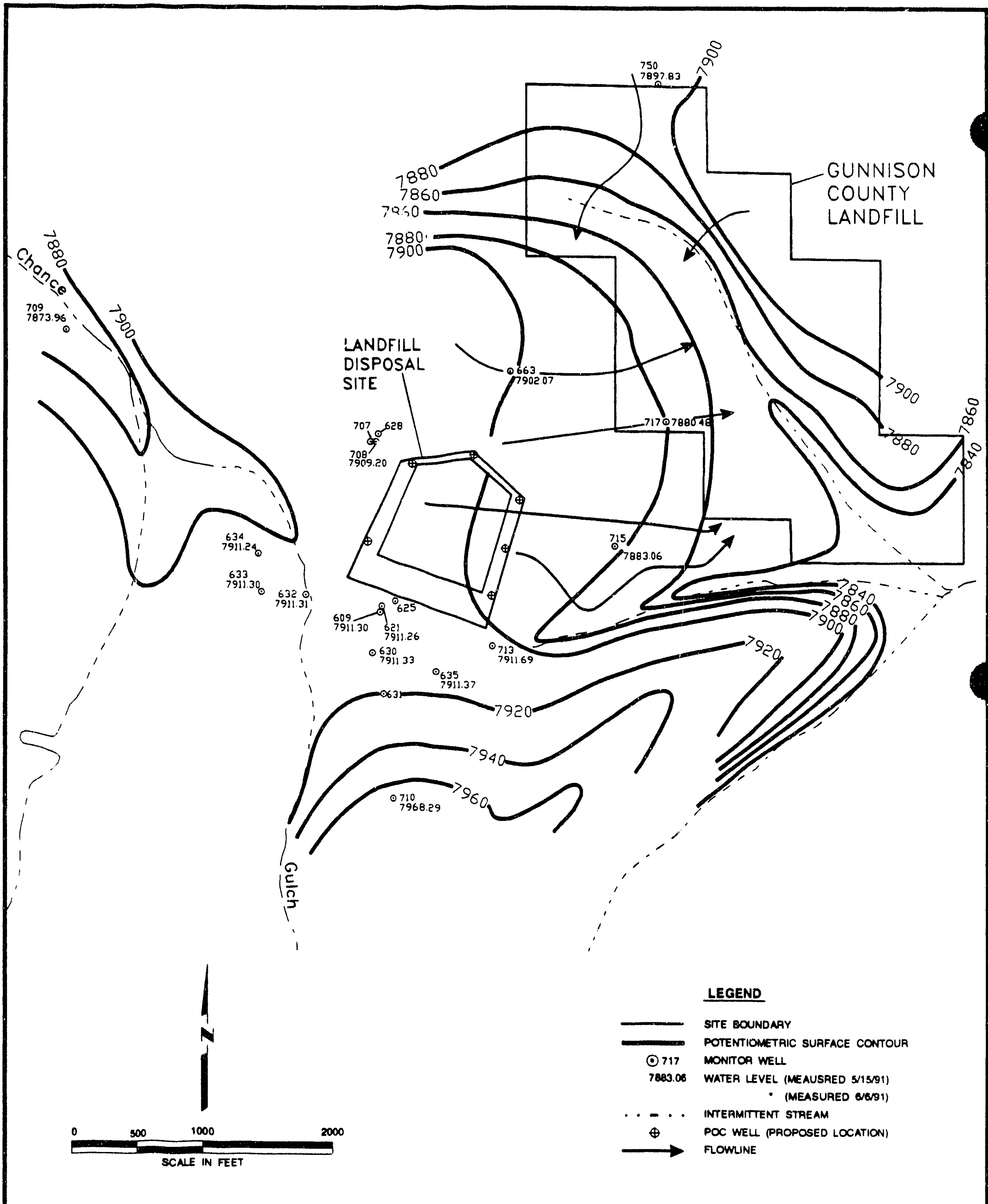

FIGURE 3.1
PLAN VIEW OF DISPOSAL CELL, POINT OF COMPLIANCE, AND GROUNDWATER MONITORING NETWORK AT THE GUNNISON DISPOSAL SITE

natural variability must be considered when defining excursions, and the proposed concentration limits should be reviewed and updated (if required) annually to incorporate additional background water-quality data.

3.5 CORRECTIVE ACTION PLAN

The DOE is required by 40 CFR 192.02(c) to provide an evaluation of alternative corrective actions that could be implemented if the disposal cell monitoring program indicates that the unit is not performing adequately. The DOE will consider reasonable failure scenarios of the disposal unit and demonstrate that corrective actions could be implemented no later than 18 months after detecting an excursion.

The Gunnison disposal cell has been designed and will be constructed to perform for the mandated design life of 1000 years. The design of the cell has incorporated standard safety factors, and should therefore perform for a period of greater than 1000 years with minimal maintenance. It is not anticipated that the designed Gunnison disposal cell will fail, because all-natural materials will be used, and because the radon barrier will be adequately protected from disruption.

4.0 CLEANUP AND CONTROL OF EXISTING CONTAMINATION

The DOE is responsible for demonstrating that cleanup or control of existing processing-related groundwater contamination at the Gunnison site will comply with the proposed EPA groundwater protection standards in Subpart B of 40 CFR 192.

The present level of site characterization is sufficient to address only whether the 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. The DOE has committed to conducting additional groundwater characterization to include water quality, groundwater flow, and aquifer properties. Hydrogeologic characterization efforts will be important in defining the groundwater system and the extent of contamination related to uranium processing activities. Hydrogeologic characterization efforts (e.g., determination of aquifer thickness, hydraulic properties, the relationship between the alluvial aquifer system and deeper groundwater systems, and contaminant plume characteristics) will be important in developing and evaluating groundwater restoration alternatives. A conceptual groundwater restoration strategy must be developed, modeled, and/or tested on bench mark and pilot scales. Realistic concentration limits and a groundwater cleanup standard can be proposed after this has been performed.

Based on the current level of characterization at the Gunnison processing site, cleanup of groundwater in the uppermost aquifer, the alluvial and terrace gravels, will be necessary, by active or passive means, because the concentration of uranium, a hazardous constituent in groundwater, exceeds the EPA MCL. Historically, concentrations of uranium that exceed the MCL have occurred in groundwater samples from domestic and DOE monitor wells more than 2000 feet downgradient of the processing site. This represents a risk to human health and the environment.

The DOE and the Colorado Department of Health have jointly developed a program for testing water from Gunnison homes potentially affected by groundwater contamination from the Gunnison tailings. The program is designed to determine concentrations of uranium in groundwater used by residents near the tailings site. The testing program and a health risk assessment undertaken by the DOE have determined there is some potential risk to the residents from the use of groundwater in the uppermost alluvial aquifer. However, there is no current risk to the residents, because those in the affected area are supplied with bottled water, and a longer-term solution, a community water system, is currently being developed (DOE, 1991). The DOE is continuing to monitor water quality in both the DOE monitoring wells and selected nearby domestic wells. This continuing data collection will provide a source of feedback regarding the water quality on the site and downgradient from the mill site, as a measure of tracking the risk to human health and the environment.

As mentioned above, the DOE has committed to supplying an alternate water source to the affected water users. These private residences are located southwest of the processing site, including the Dos Rios subdivision, residents along Goodwin Lane (adjacent to the western boundary of the processing site), and ValCo south of the site. The proposed alternate water supply will consist of a county water system, using surface water from the Gunnison River, which will be treated and distributed to residents through a water distribution system.

REFERENCES

DOE (U.S. Department of Energy), 1991. Final Environmental Assessment of the Provision of a Water Supply System at Gunnison, Colorado, UMTRA DOE/EA-0529, DOE UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1989. Technical Approach Document, Revision II, UMTRA DOE/AL-050425.0002, DOE UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

EPA (U.S. Environmental Protection Agency), 1982. Test Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA600/4-82-057, J. E. Longbottom and J. J. Lichtenburg, eds., Test Methods No. 606.

Parkhurst et al. (D. L. Parkhurst, D. C. Thorstenson, and D. N. Plummer), 1980. PHREEQE - A Computer Program for Geochemical Calculations, U.S. Geological Survey Water Resources Investigation 80-96, Washington, D.C.

Rose et al. (A. W. Rose, H. E. Hawkes, and J. S. Webb), 1979. Geochemistry in Mineral Exploration, Academic Press, New York, New York, p. 559.

USDA (U.S. Department of Agriculture), 1985. WORM, Water and Solute Movement in the Root Zone, User's Manual, U.S. Salinity Laboratory, Riverside, California.

Van Genuchten, M.Th. and D.R. Nielsen, 1985. "On Describing and Predicting the Hydraulic Properties of Unsaturated Soils," Annales Geophysicae, Vol. 3, No. 5, 1985.

Verschueren, K., 1983. Handbook of Environmental Data on Organic Chemicals, Van Nostrand Reinhold, New York, New York.

Wedepohl, K. H., 1978. Handbook of Geochemistry, Springler-Verlag, New York, New York, Vol. II-4, p. 50-I-1 and Vol. II-5, p. 81-H-1.

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