# ENCLOSURE 3

TECHNICAL EVALUATION REPORT
UMETCO MINERALS CORPORATION DESIGN FOR ENHANCEMENT OF THE PREVIOUSLY APPROVED RECLAMATION PLAN FOR THE ABOVE-GRADE INACTIVE TAILINGS IMPOUNDMENT

DATE: June 21, 1999

DOCKET NO. 40-0299 LICENSE NO. SUA-648

LICENSEE: Umetco Minerals Corporation (Umetco)

FACILITY: Above-Grade Inactive Tailings Impoundment, East Gas Hills Uranium Mill Site, Natrona County, Wyoming

PROJECT MANAGER: E. Brummett

TECHNICAL REVIEWERS: J. Weldy and G. Ofoegbu (Center for Nuclear Waste Regulatory Analyses), C. Thornton and S. Abt (Colorado State University)

SUMMARY AND CONCLUSIONS:

The U.S. Nuclear Regulatory Commission (NRC) staff has completed its review of the proposed modification of the previously approved reclamation plan for the above-grade inactive tailings impoundment (Impoundment) at the Umetco Minerals Corporation's (Umetco) Gas Hills, Wyoming site. This enhancement will replace the vegetative cover with riprap erosion protection, will extend the radon barrier to accommodate closure of the toe drain system, and will cover additional areas of contaminated soils. The NRC staff concludes that the proposed enhanced impoundment design will meet NRC requirements stated in 10 CFR Part 40, Appendix A, Criteria 4(c), (d), (e), and 6(1), with regard to reasonable assurance of stability and control of the contaminated material; and limitation of the radon flux from the disposal area to the atmosphere to 20 picocuries per square meter per second (pCi/m$^2$/s) for a period of 1,000 years, or in any case, at least 200 years. Compliance with Criterion 6(7), regarding disposal to minimize further maintenance, was also acceptably demonstrated. Criterion 6(7) also requires, in part, that licensees address the control of nonradiological hazards associated with the wastes in planning and implementing closure. This aspect of reclamation is primarily addressed in the groundwater protection program. However, control of the tailings and other wastes by the proposed cover design would also control the escape of the nonradiological hazardous wastes from the Impoundment.

DESCRIPTION OF LICENSEE'S AMENDMENT REQUEST:

Umetco submitted an enhancement to the previously approved reclamation plan for the Impoundment by letters dated October 6 and October 28, 1997, and requested amendment of license SUA-648 to reflect approval of the plan. An estimate of the additional cost for the enhanced design was submitted to the NRC on March 9, 1998, approved by NRC September 17, and the surety bond amount was appropriately increased on September 21, 1998, to include the cost of the enhanced design. The enhanced reclamation plan was modified and clarified in response to NRC requests for additional information, by letters, memorandums, and reports dated May 22, June 26, July 20, July 28, September 8, September 15, and November 23, 1998, as well as April 9 and June 7, 1999.

BACKGROUND:

The Umetco uranium mill site is located in the East Gas Hills area of central Wyoming, 50 miles (80 km) southeast of Riverton, and west of East Canyon Creek. The above-grade tailings impoundment was operated between 1960 and 1979. The original impoundment was constructed in 1960, and this impoundment continued to be enlarged between 1969 and 1974 by the construction of four terraced earth-filled dams.

The currently approved reclamation plan consists of the submitted plan modified by NRC requirements that are specified in License Condition No. 54. The requirements are summarized below.

1. Embankment slopes no steeper than 10h:1v are required.

2. Reclaimed tailings and the experimental heap leach are to be covered by a minimum of 10 feet of cover material that meets specified thickness, testing, and placement requirements related to the clay cap, filter material, overburden, spoils, riprap, and topsoil.

3. The topsoil is not to be ripped into the spoils materials.

4. The water retention structure east of the above-grade impoundment is to be removed, and drainage in the area is to be reestablished.

5. The schedule and sequence of reclamation activities is specified.

6. The instrumentation monitoring frequency is specified.

7. Construction details for the reclamation cover, including compaction specifications, testing periodicity, and inspection and reporting requirements are defined.

The reclamation of the Impoundment was completed between 1985 and 1992, except for the 6 inches (15 cm) of topsoil and grass seed. In a letter dated August 2, 1991, the NRC requested that Umetco review the reclamation plan for the above-grade tailings impoundment to evaluate compliance with the reclamation criteria contained in 10 CFR Part 40, Appendix A. This review was requested because NRC was concerned that some previously approved reclamation plans might not meet the 10 CFR Part 40, Appendix A requirements considering more recently developed information on seismic accelerations and on the design of structures to prevent erosion damage and to attenuate radon. Subsequently, the NRC published its Final Position on Review of Previously Approved Reclamation Plans on July 18, 1995. This position stated that previously approved reclamation plans would be considered final NRC actions so long as the NRC staff could confirm that the reclamation was performed in accordance with the design and that any designs that had degraded before transfer to the long-term custodian would be repaired. Additionally, the licensee would be required to justify that the reclamation design met 10 CFR Part 40, Appendix A requirements considering the observed degradation (erosion gullies on the Impoundment side slopes).

In view of the NRC position on acceptance of previously approved reclamation plans and license termination requirements, Umetco re-examined the Impoundment reclamation design and the completed work, and concluded that license termination would not be possible with the existing erosion protection design. Accordingly, the enhanced reclamation design provides for the following changes:

1. The previously approved vegetative cover will be replaced by rock riprap erosion protection.

2. The cover at the toe of the Impoundment will be extended north and east to accommodate abandonment of the toe drain system and to provide attenuation of radon from deposits of contaminated soils that were not covered by the original barrier.

3. A channel modification, including installation of erosion protection, will be made to address erosion that has occurred along the toe of the east side of the Impoundment at East Canyon Creek.

The enhanced reclamation plan required NRC staff evaluation in three technical areas: (1) surface water hydrology and erosion protection, (2) geotechnical design and testing, and (3) radon attenuation. Site surface (soil and buildings) and groundwater cleanup will be addressed in other documents. The seismic evaluation was performed previously by the NRC and the proposed seismic design was approved January 24, 1996.

TECHNICAL EVALUATION:

## 1.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

### 1.1 Introduction

This section of the technical evaluation report (TER) describes the NRC staff review of surface water hydrology and erosion protection issues related to long-term stability. The review focused on compliance with 10 CFR Part 40, Appendix A, Criteria 4(c) and (d) and 6(1) that require reasonable assurance of stability and control of contaminated material. Review areas that are covered include: (1) drainage design, (2) estimates of flood magnitudes, (3) water surface elevations and velocities, (4) sizing of riprap for erosion protection, (5) long-term durability of the erosion protection, and (6) testing and inspection procedures to be implemented during construction.

### 1.2 Hydrologic Description

To comply with NRC regulations which require stability of the tailings for 1,000 years to the extent reasonably achievable and in any case for 200 years, the licensee proposes to reclaim the tailings impoundment and to protect the tailings from flooding and erosion. The design basis events for design of erosion protection include the probable maximum precipitation (PMP) and the probable maximum flood (PMF). The PMP and PMF are based on estimated worst case meteorological conditions for a site, and both events are considered to have very low occurrence probabilities during the 1,000-year stabilization period.

The Gas Hills site is located within the Wind River Basin of central Wyoming. This area has a semi-arid climate with low precipitation and wide seasonal fluctuation in temperature. Average annual precipitation for the site is 23 cm (9 inches) (NRC, 1982) falling mainly in the spring and summer in the form of wet snow and rain. The mean annual snow fall is 183 cm ( 72 inches), and pan evaporation averages 116 cm (46 inches) per year. Wind gusts prevail from the southwest and average from 5 to 7.5 m/sec [11 to 17 miles per hour (mph)]; however, gusts from 25 to 35 m/sec (60 to 78 mph) have been recorded.

Two drainage basins are located at the site, and they only contain water a portion of the year. East Canyon Creek is approximately 213 m (700 feet) from the impoundment and drains generally from south to north. Umetco Creek discharges into East Canyon Creek approximately 61 m (200 feet) downstream of the east edge of the Impoundment. Slopes for each creek range from 80 percent in the upper portion of the basins to 3 percent in the lower portion of the basins. Vegetation is sparse, consisting of sagebrush and native grasses with some trees. The site is positioned on strata of the Eocene Wind River Formation, which has been segmented into upper and lower units (Geraghty and Miller, 1996). The Upper Wind River aquifer is saturated only beneath the southern portion of the site, where it exists under unconfined conditions. The Lower Wind River aquifer is located beneath the entire site, changing from an unconfined aquifer in the northern portion of the site to a confined aquifer in the southern portion. A mudstone unit between 6 and 12 m (20 and 40 feet) thick is the confining unit between the Upper and Lower Wind River aquifers. Perched ground water occurs above the mudstone unit in the northern portion of the site. Groundwater flow in the Upper Wind River aquifer is to the south-southwest, whereas flow in the Lower Wind River aquifer is primarily to the west (Geraghty and Miller, 1996).

### 1.3 Drainage Design

The licensee prepared a drainage design to protect the toe of the above-grade inactive tailings impoundment adjacent to East Canyon Creek. The design incorporates a determination of the design flood, the hydraulic characteristics of the channel during the design flood, and the sizing of channel riprap. In addition, the licensee performed calculations utilizing the Safety Factors Method (Stevens et al., 1976) to size riprap for protection of the impoundment against overland flow. The design includes calculations of potential scour at the toe of the impoundment to ensure adequate stability for the impoundment. The NRC staff concludes that appropriate methods were used for preparing the drainage design and that the design is acceptable.

### 1.4 Estimates of Flood Magnitudes

Umetco used methods accepted by the NRC staff for the design flood determination. The PMP was determined to support overland flow computations for the tailings area and for drainage from both East Canyon and Umetco Creeks. The calculation of peak flood discharges for design features was performed in several steps. These steps included: (1) selection of a design rainfall event; (2) determination of drainage areas; (3) calculation of times of concentration ($t_c$s); (4) determination of infiltration losses; (5) determination of appropriate rainfall distributions corresponding to the computed $t_c$s; and (6) calculation of flood discharges.

Input parameters derived from each of these steps were used to determine the peak flood discharges to be used in the water surface profile modeling and in the final determination of rock sizes for erosion protection.

### 1.4.1 Selection of the Design Rainfall Event

A key process affecting long-term stability is surface water erosion. To mitigate the potential effects of surface water erosion, an appropriately conservative rainfall event on which to base the flood protection designs must be selected. The licensee utilized a PMP computed by deterministic methods and based on site-specific hydrometeorological characteristics. The PMP is defined as the most severe possible rainfall event that could occur as a result of a combination of the most severe meteorological conditions occurring over a watershed. The staff has concluded that the likelihood of such an event during the 1,000 year required stability period is acceptably low. Accordingly, the NRC staff concludes that the PMP provides an adequate design basis.

The licensee employed hydrometeorological reports for the region in determining the PMP. This technique is widely used and provides straightforward results with minimal variability. The NRC staff concludes that the use of these reports to derive PMP estimates is acceptable.

PMP values were estimated by the licensee using Hydrometeorological Report 55A (HMR-55A) (Hansen et al., 1988). The 1-hour, 2.6 $km^2$ (1 square mile) storm was selected as a conservative precipitation event for the Gas Hills site. The depth of precipitation for this event is 24.6 cm (9.7 inches). The base PMP for small drainage areas [less than 1,295 $km^2$ (500 square miles)] is the 1 hour, 2.6 $km^2$ (1 square mile) storm. The licensee utilized plate VI-b of HMR-55A to determine the depth of PMP precipitation for an elevation of 1,520 m (5,000 feet) to be 24.6 cm (9.7 inches). For East Canyon Creek, the licensee adjusted the depth based on elevation and the maximum persisting 12-hour, 1,000-millibar dew points for the entire year. Given the site data, the licensee determined an elevation adjustment factor of 0.89, making the base PMP for the East Canyon Creek drainage above the tailings impoundment 21.8 cm (8.6 inches).

As indicated in HMR-55A, the PMP can further be reduced since the drainage area at the site is larger than 2.6 $km^2$ (1 square mile). Combining the drainage areas of Umetco and East Canyon Creeks yields a total drainage area of 12 $km^2$ (4.65 square miles). Figure 12-12 of HMR-55A shows that the licensee could utilize a reduction factor of 0.94 for a 6-hour duration storm, and a reduction factor of 0.91 for a 1-hour duration storm. Using these factors, the licensee determined that the depths associated with a 1-hour PMP and a 6-hour PMP were 19.8 cm (7.8 inches) and 27.7 cm (10.9 inches), respectively. The licensee's procedures for estimating the PMP were reviewed and it was concluded that a 1-hour PMP of 19.8 cm (7.8 inches) and a 6-hour PMP of 27.7 cm (10.9 inches) are acceptable.

### 1.4.2 Determination of Drainage Areas

Two drainage basins contribute to the flow in East Canyon and Umetco Creeks. These basins were divided into eight sub-basins to evaluate flood hydrographs at multiple points. Umetco determined the basin areas by digitizing sub-basin boundaries obtained from a report prepared by Grant Environmental (1995). Characteristics of the sub-basin areas are presented in

Table 1. Based on a review of the licensee determination, the NRC concludes that the sub-basin characteristics were properly determined.

**Table 1: Summary of Sub-Basin Characteristics**

| Sub-Basin | Sub-Basin Area (square miles) | Length of Longest Flow Path (miles) | Elevation Change (feet) |
|---|---|---|---|
| Basin A | 0.729 | 2.10 | 640 |
| Basin B | 0.465 | 1.36 | 640 |
| Basin C | 0.992 | 1.87 | 680 |
| Basin D | 0.491 | 1.25 | 210 |
| Basin E1 | 0.433 | 0.94 | 145 |
| Basin E2 | 0.187 | 0.81 | 166 |
| Basin F | 1.054 | 1.98 | 226 |
| Basin G | 0.303 | 0.54 | 179 |

1.4.3 Calculation of Times of Concentration

The $t_c$ is the period required for runoff to reach the outlet of a drainage basin from the most remote point in that basin. The $t_c$s were estimated by the licensee using the Kirpich Method [U.S. Bureau of Reclamation (USBR), 1977]. This method is generally accepted in engineering practice and is considered by the staff to be appropriate for estimating $t_c$s. Based on a review of the calculations provided, the staff concludes that the $t_c$ values used by the licensee were acceptably derived.

1.4.4 Determination of Infiltration Losses

The peak runoff rate is also dependent on the amount of precipitation that infiltrates into the ground and therefore does not contribute to flood flows. If the ground is saturated from previous rains, very little rainfall will infiltrate and most will become surface runoff. The licensee used the Soil Conservation Service Curve Number (CN) Method (SCS, 1982) to determine the amount of precipitation that produces runoff. The curve number estimate was obtained from Table A-4 of the USBR document "Design of Small Dams" (USBR, 1977). The CN of an area is an indication of the amount of precipitation that will result in runoff based on the soil and vegetation characteristics of a drainage area and on the soil moisture levels existing prior to the design storm event. In estimating CN values, the licensee assumed an antecedent moisture condition (AMC) III, indicating wet conditions prior to the occurrence of the PMP event. This approach resulted in conservative PMFs because the saturated soil conditions limit the infiltration that will occur and maximize the runoff. Ground covers for East Canyon Creek and Umetco Creek were classified as sagebrush (poor to fair) by the licensee.

Considering these factors, the licensee utilized a CN value of 86 in the HEC-1 analysis. The NRC staff concludes the methods used to assess infiltration were appropriate.

### 1.4.5 Determination of Rainfall Distribution

Once the PMP is determined, the rainfall intensities corresponding to shorter rainfall durations and $t_c$s must be estimated. A typical PMP value is for a period of about 1 hour. If the $t_c$ is less than 1 hour, the data presented in the various hydrometeorological reports must be extrapolated to shorter time periods. The licensee utilized an SCS Type II distribution. Type II distributions represent regions in which the high rates of runoff from small areas are usually generated from summer thunderstorms. The licensee obtained the distribution information from numerical data presented in Table 14-3-1 of Hansen et al. (1988). Selecting 3 minutes as the time-series data interval yielded 20 data points per hour to describe the storm hyetograph. The intensities were assembled by computing the average intensities for each time period outlined in Table 14-3-1 of Hansen et al. (1988). Linear interpolation between average intensity pairs resulted in fitting parameters that permitted the licensee to estimate the storm intensity for each minute of a 24-hour Type II storm.

Using the estimated intensities, the licensee calculated the cumulative storm precipitation and selected the 1- and 6-hour segment from the center of the storm since these segments included the greatest storm intensities. The rainfall distributions corresponding to the 1-hour and 6-hour PMP of 19.8 cm (7.8 inches) and 27.7 cm (10.9 inches), respectively were obtained by multiplying the ratio of accumulated rainfall to total rainfall (in a 1-minute time series) by the total rainfall amount. Storm hyetographs were then constructed on a 3-minute time series interval for input into HEC-1. The NRC staff concludes that techniques used by the licensee for calculating rainfall distribution are acceptable.

### 1.4.6 Computation of Flood Discharges

The licensee used two methods for determining the peak overland flow discharge caused by the design precipitation. Peak discharges from overland flow on rock protected areas were calculated using the Rational Formula (USBR, 1977). Peak discharges for channelized flow in Umetco Creek and East Canyon Creek were determined using the U.S. Army Corps of Engineers (USACOE) HEC-1 computer model (USACOE, 1988).

#### 1.4.6.1 Overland Flow

To estimate PMF peak discharges for overland flow calculations on rock protected areas, the licensee used the Rational Formula. This method provides a simple procedure for estimating flood discharges that is recommended by the NRC (NRC, 1990). A conservative value of 1.0 was used as a runoff coefficient. The licensee selected a series of flow paths on the proposed reclaimed impoundment that were designed to achieve complete areal coverage of the reclaimed surface and to represent an extreme overland flow condition based on slope angle and slope length. Each flow path was divided into sections of uniform slope for the runoff analysis. The licensee then applied the Rational Formula to determine discharges on segments of the flow path. The $t_c$, area, and unit width were summed moving down gradient on each flow path, resulting in a value for cumulative discharge. For the flow paths with a very small $t_c$, the results were essentially a summation of peak flows. As the total $t_c$ increased, the precipitation intensity decreased slightly, with the result that the discharge is slightly less than a summation of peak flows.

Table 2 summarizes the results of the overland flow calculations for each of the seven flow paths analyzed on the impoundment. The licensee utilized the Stephenson Method (Stephenson, 1979) for sizing riprap and determined that three riprap sizes [1.3 cm (0.5 inch), 7.6 cm (3.0 inch), and 15.2 cm (6.0 inch) $D_{50}$)] would be necessary to provide adequate protection for the impoundment from overland flow. Further discussion on riprap sizing is presented in sections 1.5.1 and 1.6.1 of this TER. Based on a review of the calculations including $t_c$, rainfall intensity, runoff, and rock sizing, the NRC staff concludes that the estimates were made using appropriate techniques and are acceptable.

**Table 2: Summary of Overland flow calculations**

| Profile Identification | Profile Length (ft) | PMP Peak Intensity (in/hr) | PMP Peak Discharge (cfs/ft) |
|---|---|---|---|
| A | 920 | 48.2 | 0.712 |
| B | 1610 | 48.2 | 1.154 |
| C | 1960 | 35.2 | 1.175 |
| D | 2820 | 30.5 | 1.402 |
| D1 | 3030 | 30.5 | 1.453 |
| E | 2460 | 27.9 | 1.250 |
| F | 960 | 31.4 | 0.648 |

1.4.6.2 Channelized Flow

Peak PMF discharges and runoff hydrographs resulting from the design storm were determined for the drainage basin feeding Umetco and East Canyon Creeks using the HEC-1 computer program. The cumulative 1-hour PMP rainfall distribution was input into the model in 3-minute increments.

The HEC-1 model allows preparation of runoff hydrographs from individual sub-basins, combining hydrographs from separate sub-basins, and routing individual or combined hydrographs to downstream points. The licensee included channel routing in the HEC-1 analysis. Table 3 summarizes the peak PMF discharges for the 1-hour and 6-hour PMP as determined by the licensee in the HEC-1 analysis. Since the 6-hour PMF values are larger than the 1-hour PMF values, the 6-hour PMF values were used by the licensee to size riprap for the toe of the above-grade tailings impoundment adjacent to East Canyon Creek.

Because the peak discharges for the 6-hour storm are larger than the peak discharges from the 1-hour storm, the licensee also used the 6-hour storm as the design flood. A peak discharge of 349 $m^3/s$ (12,461 cfs) (hydrograph location 3) was used for East Canyon Creek and 445 $m^3/s$ (15,910 cfs) (hydrograph location 5) was used for Umetco Creek. Below the confluence, a peak discharge of 777 $m^3/s$ (27,755 cfs) (hydrograph location 6) was used as the design flow. Based on a review of the calculations provided, the staff concludes that the PMF values used by the licensee were acceptably derived.

Table 3: Summary of Peak Flows

| Hydrograph Location | Contributing Sub-Basins | PMF Peak Flow 6-hour (cfs) | PMF Peak Flow 1-hour (cfs) |
|---|---|---|---|
| 1 | A, B | 8,071 | 8,046 |
| 2 | A, B, E1 | 11,168 | 11,153 |
| 3 | A, B, E1, E2 | 12,461 | 12,445 |
| 4 | C, D | 10,300 | 10,312 |
| 5 | C, D, F | 15,910 | 15,715 |
| 6 | A, B, C, D, E1, E2, F | 27,755 | 27,486 |
| 7 | A, B, C, D, E1, E2, F, G | 28,950 | 28,604 |

1.5 Water Surface Profiles and Channel Velocities

Following the determination of the peak flood discharge, Umetco determined the resulting water levels, velocities, and shear stresses associated with that discharge. These parameters provide the basis for the determination of the required riprap size and layer thickness required to ensure stability during the design flooding event.

The staff evaluated the licensee's proposal to provide a low-flow channel to augment the wetland area in East Canyon Creek (submittal of June 7, 1999). In that proposal, the reconfigured channel of East Canyon Creek near the above-grade impoundment will be increased in size by excavating a 0.6 by 1-meter (2 by 40-foot) pilot channel to improve wetlands habitat. Based on evaluation of the water surface profiles previously provided by the licensee and a site visit to the area, the staff concludes that the small increase in channel cross-sectional area will have little or no effect on water surface profiles or velocities during an occurrence of a major flood. The staff further concludes that the wetlands design features provided by Umetco will not have any effect on design features that provide long-term stability against erosion.

1.5.1 Overland Flow Paths

In determining the riprap requirements for the overland flow paths, Umetco used the Safety Factors Method (Stevens et al., 1976) and the Stephenson Method (Stephenson, 1979). The Safety Factors Method was used for rock design for slopes with less than 10 percent grade, and the Stephenson Method was used for slopes of 10 percent grade and greater. The Abt Method (Abt et al., 1987) was used to determine Manning's *n* for all rock mulch areas. The validity of these design approaches has been verified by the NRC staff through the use of flume tests at Colorado State University. Therefore, the NRC staff concludes that the procedures and design approaches used by the licensee are acceptable for designing riprap erosion protection.

Input parameters and design methods for riprap sizing are discussed further in Section 1.6 of this TER.

### 1.5.2 Channelized Flow

Using the peak PMF discharges previously discussed, the licensee determined channel conveyance characteristics and water surface profiles for Umetco and East Canyon Creeks using the USACOE HEC-RAS computer program (USACOE, 1997). The NRC staff considers this to be an acceptable computational method for estimating water surface elevations and flow characteristics. The licensee used a channel Manning's *n* of 0.035 and an overbank Manning's *n* of 0.04 in the HEC-RAS analysis. The design floods determined using the analyses presented earlier in this TER were used as input to the HEC-RAS computer code to determine the velocities, water levels, and shear stresses associated with each discharge. The NRC staff concludes that these methods are acceptable.

## 1.6 Erosion Protection

The ability of a riprap layer to resist the velocities and shear forces associated with surface flows is related to the size and weight of the stones that make up the layer. Typically, riprap layers consist of a mass of varying sized rocks that are well graded. Because of the variation in rock sizes, design criteria are generally expressed in terms of the median stone size ($D_{50}$). Depending on the rock source, variations occur in the sizes of rock available for production and placement on the reclaimed pile. It is necessary to ensure that the variation in rock sizes is not extreme, and design criteria for developing acceptable gradations are provided by various sources (e.g., USACOE, 1984; Simons and Li, 1982).

### 1.6.1 Riprap Sizing

The NRC reviews focused on the $D_{50}$ sizes proposed by the licensee to determine if they are adequate for all areas of the design. Utilizing the hydraulic parameters estimated by HEC-RAS, the licensee applied the Safety Factors method to size riprap for erosion protection along the left bank of East Canyon Creek.

Twenty-eight cross sections along East Canyon Creek were analyzed using the HEC-RAS code. While the Safety Factors Method suggests that 80 percent of the depth at the toe be utilized in calculating the shear stress, the licensee used the hydraulic depth in the left overbank area as the design depth. Required riprap $D_{50}$ sizes along the left bank of East Canyon Creek are 50.8 cm (20 inch) riprap placed 0.91m (3 feet) thick from station 11+00 to station 6+00, and 40.6 cm (16 inch) riprap placed 0.61 m (2 feet) thick from station 6+00 to station -2+50. Based on staff analysis of the riprap sizing and thickness calculations, the riprap design is acceptable.

In order to size the riprap for overland flow protection of the Impoundment top and side slopes, the licensee used seven profiles to form a representative model of the range of slopes existing across the impoundment. Several locations along each profile were selected by the licensee to apply NRC-recommended procedures for sizing riprap (NRC, 1990). For slopes of 10h:1v or less the Safety Factors Method was utilized, and for slopes greater than 10h:1v the Stephenson Method was applied. Results of these analyses indicated that three rock sizes were necessary: a 1.3 cm (0.5 inch) riprap placed 15.2 cm (6 inches) thick, 7.6 cm (3 inch) riprap placed 15.2 cm

(6 inches) thick, and 15.2 cm (6 inch) riprap placed 30.5 cm (1 foot) thick. The placement of riprap was evaluated and determined to be acceptable.

The licensee conducted an analysis to determine if a filter layer of well-graded rock was necessary to prevent erosion of the *in situ* base material underlying the riprap. Interstitial flows through the riprap layer were calculated and compared to permissible velocities as recommended by the NRC (1990). For all locations on the top and side slopes of the embankment, the average velocity through the voids was significantly less than the permissible velocity. This result indicates that the riprap protection layers will be erosionally stable for the PMF across the entire impoundment and that no filter layer is required. Based on an analysis of these calculations, the staff concludes that the rock size, thickness, and stability determinations are acceptable.

### 1.6.2 Toe Protection

Scour depth in East Canyon Creek was calculated using the Regime Equations Method suggested by the U.S. Bureau of Reclamation (Pemberton and Lara, 1984). A conservative PMF discharge of 777 $m^3/s$ (27,755 cfs) was used in the analysis. Based on the Regime Equations and the PMF, the calculated scour depth along the toe of East Canyon Creek is 2.9 m (9.4 feet). A hand auger was used at two locations along East Canyon Creek to determine the depth to bed rock along the impoundment toe. The licensee determined that the depth to bedrock along the impoundment toe is approximately 0.9 to 1.2 m (3 to 4 feet) below the existing grade and 1.8 to 2.1 m (6 to 7 feet) below the design grade. Riprap toe protection will be buried to the calculated scour depth of 2.9 m (9.4 feet) or the depth to competent bedrock, whichever is shallower. Upon review of the calculations, the NRC staff concludes that the design for toe protection is acceptable.

### 1.6.3 Riprap Gradations

As discussed in Section 1.6.1above, five riprap sizes have been proposed for the enhanced reclamation plan. The five riprap sizes have been labeled in the plan as Type A through E. Three listed sizes are for overland flow protection, and two are for protection of the left bank of East Canyon Creek. The placement of riprap was evaluated by the reviewers and was determined to be acceptable. The proposed riprap sizes and gradation are acceptable to the staff.

### 1.6.4 Rock Durability

NRC regulations require that control of residual radioactive materials be effective for up to 1000 years, to the extent reasonably achievable, and in any case, for at least 200 years. The previous sections of this TER examined the ability of the erosion protection to withstand flooding events reasonably expected to occur in 1,000 years. In this section, rock durability is considered to determine if there is reasonable assurance that the rock will remain intact for 1,000 years.

Rock durability is defined as the ability of a material to withstand the forces of weathering. Factors that affect rock durability are: (1) chemical reactions with water; (2) saturation time; (3) temperature of the water; (4) scour by sediments; (5) windblown scour; (6) wetting and drying; and (7) freezing and thawing.

To assure that the rock used for erosion protection remains effective for up to 1000 years as required by Criterion 6 of 10 CFR Part 40, Appendix A, potential rock sources were tested and evaluated to identify acceptable sources of riprap using the procedure presented in Appendix D of "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites" (NRC, 1990).

### 1.6.5 Testing and Inspection of Erosion Protection

The staff reviewed and evaluated the testing, inspection, and quality control procedures proposed by the licensee for the erosion protection materials and design features. The review included evaluation of programs for durability testing, gradation testing, rock placement, and verification of rock and filter layer thickness.

Based on a review of the proposed procedures, the staff concludes that the gradation testing program will ensure that rock and filter layers with acceptable gradations will be provided. The testing program is equivalent to several which were previously approved by the NRC staff and have been implemented at other sites during reclamation construction.

## 1.7 Channel Siltation

Small amounts of sand, silt and clay are expected to be transported through the tributary watersheds and into the drainage channels. Since most of the drainage channel is protected with riprap, and the velocities in the channel are sufficiently high (requiring riprap for erosion protection), the limited amount of sediment that may build up in the channel is expected to be transported out of the channel during any substantial discharge. The staff has reviewed the siltation analysis and concludes that the limited expected deposition or build up of sediments is acceptable.

## 1.8 References


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## 2.0 Geotechnical Design

This section of the TER discusses aspects of the above-grade tailings impoundment enhanced design related to geotechnical stability. Review areas that are covered include seismic design (slope stability and liquefaction potential), settlement analysis, and radon barrier cracking potential. The review focused on compliance with 10 CFR Part 40, Appendix A, Criteria 4(c), and (e), and 6(1) that require reasonable assurance of stability and control of the contaminated material.

### 2.1 Seismic Design

The NRC staff has previously reviewed and accepted the seismic design for the Umetco above-grade tailings impoundment. In accordance with NRC policy, the seismic acceptability of the design will be reevaluated only if a significant change in the geometry of the tailings pile is proposed. The enhanced reclamation design that is assessed in this TER does not include significant changes in the tailings pile geometry from the previously approved plan. However, the slope stability and liquefaction potential aspects of the seismic design were evaluated because updated information on these analyses was provided by the licensee.

### 2.1.1 Slope Stability

The slope stability evaluation was conducted through static and pseudo-static analyses of a critical slope section selected by the licensee. The analyses were performed using a commercially available computer code, SLOPE/W (GEO-SLOPE International, Ltd., 1995). A peak ground acceleration (PGA) of 0.3 g, as recommended for the site by Bernreuter et al. (1994) was used in the pseudo-static analyses. Values of total unit weight, friction angle, and cohesion used for these analyses were taken from Umetco reports that have been previously accepted by NRC. Potential failure surfaces based on circular, block, and infinite-slope failure modes were considered in the analyses. The analyses were conducted using both current and long-term pore pressure distributions. The results indicate minimum safety factors of 3.26 and 1.25 under static and seismic loading conditions, respectively. These safety factors satisfy criteria in NRC Regulatory Guide 3.11 (NRC, 1977). The NRC staff concludes that the slope stability analysis for the enhanced reclamation design is acceptable. The above-grade tailings impoundment has a slope less than 1v:10h, which is quite flat. Additionally, the licensee has appropriately selected the seismic coefficient value following Bernreuter et al. (1994) for analyzing the stability of the impoundment. Although some areas of the impoundment have been identified to be potentially liquifiable with the current location of the phreatic surface for a PGA of 0.3 g, as discussed in section 2.1.2 below, the risk is quite small and will decrease as the tailings are expected to complete draining during the next 25 years. Based on the above-discussed information, the NRC reviewer concludes that a pseudostatic analysis instead of a complete dynamic analysis is acceptable.

### 2.1.2 Liquefaction Potential

Liquefaction potential analyses were performed for the 1969, 1972, and 1974 tailings impoundments, which still contain saturated tailings. The tailings within the 1960 impoundment are no longer saturated and are, therefore, not susceptible to liquefaction. The analyses for the other three impoundments (1969, 1972, and 1974 tailings impoundments) were performed using site-specific properties including: (1) standard penetration test (SPT) data obtained from field tests conducted in 1997 (Shepherd Miller, Inc., 1997, Appendix H.5); (2) particle size distributions obtained (Shepherd Miller, Inc., 1997, Appendix I.5); and (3) pore pressures from pneumatic piezometers located close to the analysis points. The analyses yield factors of safety against liquefaction that are smaller than 1.0 for several calculation points, thereby suggesting a potential risk of liquefaction for the tailings pile.

The concern caused by the low factors of safety for liquefaction potential is mitigated by the consideration of other information. Results of seepage analyses (Shepherd Miller, Inc., 1997, Section 6) indicate that tailings drainage will be complete within approximately 25 years. As a result, because unsaturated soils are not subject to liquefaction, the potential for liquefaction of the tailings is likely to be eliminated during the next 25 years. The liquefaction analyses were performed using a PGA of 0.3 g, which is the recommended PGA for the site from an earthquake with a return period of about 10,000 years (i.e., an annual probability of occurrence of $1.0 \times 10^{-4}$). Because the liquefaction risk is expected to have been eliminated in about 25 years, a PGA based on a higher probability (shorter return period) would be more appropriate for the liquefaction analysis. For example, the maximum PGA for the site decreases to 0.2 g for a probability of $5.0 \times 10^{-4}$ (return period of 2,000 years) and decreases further as the probability is increased (Bernreuter et al., 1994). As a result, the calculated liquefaction risk is most likely an exaggeration of the actual liquefaction risk for the site, considering future drainage of the tailings. The NRC staff concludes that the liquefaction potential for the site has been adequately assessed and is acceptable.

## 2.2 Settlement Analysis

Settlement analyses for the enhanced reclamation design were performed for four zones that were identified to have thick deposits of slimes and that are within the boundaries of the four smaller impoundments as follows: Zones 1 and 2 in the 1972 impoundment, Zone 3 in the 1974 impoundment, and Zone 4 in the 1960/1969 impoundment. The analyses were conducted to determine the amount of settlement that has occurred from the end of tailings deposition (January 1982 for Zones 1 and 2 and January 1984 for Zones 3 and 4) through December 1996 and to predict the amount of settlement that can be expected in the future. The resultant settlement amounts were used to estimate the flow concentration factors and the cracking potential of the radon barrier. Only the amount of settlement predicted to occur after placement of the radon barrier was used in the assessment of cracking potential. The calculated pre-1997 settlements were compared with monitored settlements at four locations.

The slime-free soil layers within each zone, which range in particle size composition from silty sand to gravel, were considered incompressible relative to the layers that have significant quantities of slimes. As a result, only the slime layers were considered compressible in the settlement analysis. The analyses were performed using stratigraphic profiles and soil properties compiled from earlier field and laboratory consolidation tests and from profiles of initial void ratio and pore water pressure (Water, Waste, and Land, Inc., 1984). Stress changes corresponding to various cut-and-fill operations between the end of tailings deposition and the placement of 2.4 m (8 feet) of cover material in 1992 were accounted for in the analyses.

Reasonable agreement was obtained between measured and calculated pre-1997 settlements. However, it was determined that the number of settlement data points (two in each zone) was not sufficient to support a reasonable assessment of the cracking potential of the radon barrier. Therefore, at the request of NRC staff, the licensee conducted additional settlement analyses using tailings deposit thickness data. The additional analyses were based on an assumption that settlement from consolidation of tailings is approximately proportional to the tailings thickness. This assumption is acceptable to the NRC. The licensee developed two settlement versus thickness correlation functions based on this assumption as follows:

$s = 0.060d$ for soft to very soft silty slimes, and

$s = 0.022d$ for very loose silty sand with slimes,

where $d$ is thickness (feet) and $s$ is settlement (feet). These functions were used to predict settlement at borehole locations within each impoundment, thereby increasing the number of settlement points within each zone. The results were used to generate settlement contours.

The NRC staff concludes that the settlement analysis was completed using acceptable methods and assumptions and that the expected amount of settlement is acceptable.

## 2.3 Radon Barrier Cracking Potential

The cracking potential of the enhanced radon barrier was analyzed using a semi-empirical procedure that consisted of the following steps. First, the predicted settlement distribution was used to calculate the distribution of horizontal deflections at the top surface of the radon barrier using a semi-empirical formula developed by Lee and Shen (1969). Second, horizontal strains were calculated from the horizontal deflections by partial differentiation. Third, the horizontal strains were compared with the cracking resistance of the radon barrier using a correlation between the plasticity index and the cracking strain of cohesive soils (Morrison-Knudsen Environmental Corporation, 1988). The cracking strain for the radon barrier was determined to be $1.52 \times 10^{-3}$ using a value for plasticity index of 34 that was obtained from a previously accepted report (Umetco Minerals Corporation, 1996).

The cracking analyses were performed along the seven section lines presented in Table 4 below. Profiles of horizontal strain calculated by Umetco and independently by the NRC reviewer using the previously described procedure are similar, and yield maximum and minimum values at about the same locations on each cross section. However, Umetco's profiles have smaller gradients than the reviewer's profiles, and the values of peak strain calculated by Umetco are generally smaller than the peak strains calculated by the NRC reviewer. The reviewer's implementation of the calculation procedure described in the previous paragraph is based on fitting a quadratic curve at each settlement point along a section line using data for the point and its two neighboring points (one on either side). The second derivative of the curve is multiplied by (2/3)H, where *H* is the radon-barrier thickness, to

**Table 4: Comparison of Maximum Horizontal Strains Calculated by Umetco and NRC Reviewer**

| Cross-Section Name (Shepherd Miller, Inc., 1998, Figure 4) | Maximum Horizontal Strain ($10^{-3}$ units) on the Top Surface of the Radon Barrier from Consolidation Settlement of Underlying Tailings | |
|---|---|---|
| | Umetco | NRC Reviewer |
| 60A-60A' | 0.29 | 0.48 |
| 60B-60B' | 0.47 | 0.84 |
| 69-69' | 0.62 | 0.81 |
| 72A-72A' | 0.19 | 0.21 |
| 72B-72B' | 0.38 | 1.88 |
| 74A-74A' | 0.22 | 0.68 |
| 74B-74B' | 0.06 | 0.12 |

obtain the horizontal strain following Lee and Shen (1969). The peak strains calculated by Umetco are all smaller than the cracking strain of $1.52 \times 10^{-3}$. Peak strains calculated by the NRC reviewer are also smaller than the cracking strain except at one point on section 72B-72B' within the 1972 impoundment. The relatively high peak strain corresponds to an increase in the lateral gradient of settlement that occurs between the 0.15 m (0.5 feet) and 0.30 m (1.0 feet) settlement contours over the 1972 impoundment (Shepherd Miller, Inc., 1998, Figure 4).

The area over which this change in gradient exists is less than 10 percent of the total surface area of the Impoundment. The concern with cover cracking is that tailings may be exposed, resulting in radon emissions from the impoundment in excess of 20 pCi/m$^2$/s. To address this concern, the reviewers made the extremely conservative assumption that a cover crack occurred in the area of high strain gradient and exposed 1 percent of the tailings. Using the RADON computer code, the reviewers determined that the radon flux above the area of the cover crack would be 442.7 pCi/m$^2$/s. Using this value to calculate the average radon flux over the entire area of the pile results in a value of 9.7 pCi/m$^2$/s [(0.01) (442.7 pCi/m$^2$/sec) + 0.99 (5.33 pCi/m$^2$/s) = 9.7 pCi/m$^2$/s)]. Since this value is significantly less than 20 pCi/m$^2$/s, the NRC staff concludes that if the tailings impoundment cover cracked in the area of high strain gradient, the cover would still meet the radon flux limit of 10 CFR Part 40, Appendix A, Criterion 6(1). Additional discussion of the performance of the Impoundment radon barrier is presented in Section 3.0 of this TER. The NRC staff further concludes that the cracking potential analysis was conducted using appropriate methods and that the cracking potential has been conservatively assessed and is acceptable.

## 2.4 References

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---"Part 1, Design for Enhancement of the Previously Approved Reclamation Plan for the Above-Grade Inactive Tailings Impoundment Design Report," Fort Collins, CO, October 1997.

Umetco Minerals Corporation, "Heap Leach Reclamation Plan Modifications and Reclamation Plan for GHP No. 2/Mill Area," Grand Junction, CO, September 13, 1996.

U. S. Nuclear Regulatory Commission (NRC), "Seismic Evaluation - Reclamation Plan (License Number SUA-648) Umetco Minerals Corporation, Gas Hills, Wyoming Uranium Mill Site," Letter from J.J. Holonich to T. Gieck dated January 24, 1996.

---"Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills, Regulatory Guide 3.11," Washington, DC: Nuclear Regulatory Commission, Office of Standards Development, 1977.

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## 3.0 RADON ATTENUATION DESIGN

### 3.1 Introduction

This section of the staff evaluation of the enhanced reclamation design addresses the demonstration of compliance with that portion of Criterion 6(1) of 10 CFR Part 40, Appendix A requiring that a disposal cell design limit releases of radon (Rn-222) from uranium byproduct materials not to exceed an average (over at least 1 year) release rate of 20 $pCi/m^2/s$ from the surface of the cell for 1,000 years, to the extent reasonably achievable, but for at least 200 years.

Because radon is a gas with a short half-life (3.8 days), the amount of radon from uranium mill tailings reaching the atmosphere is reduced by restricting the gas movement long enough so that radon decays to a solid daughter that remains within the disposal cell. The physical and radiological parameters influencing the amount of radon available to the soil pore spaces and its movement are incorporated into a computer code to calculate the radon flux from the cover, or the cover thickness required to limit the flux.

This review focused on the proposed radon barrier design for the extension of the reclamation cover. The review was conducted in accordance with the NRC Final Standard Review Plan for the Review of a Remedial Action of Inactive Mill Tailings Sites under Title I of the Uranium Mill Tailings Radiation Control Act (NRC, 1993) and consisted of comprehensive assessments of the licensee's amendment request and supporting documentation.

To meet Criterion 6(1) of 10 CFR Part 40, Appendix A, a soil radon barrier is typically placed over tailings impoundments to limit long-term radon flux to less than 20 $pCi/m^2s$ averaged over the entire tailings pile. The radon flux from the cell cover is dependent on the physical and radiological characteristics of the contaminated materials and the cover soils. These characteristics include radium content, dry density, specific gravity, porosity, long-term moisture content, thickness, emanation coefficient, and diffusion coefficient. In addition, external influences, such as freeze-thaw degradation, biointrusion, erosional stability, and slope stability may also affect the radon attenuation and stability characteristics of covers, as discussed in Section 2 above. Using measured values or estimates of these parameters and factors, a computer code is used to model the radon flux through the cover. The moisture content and diffusion coefficient are the most important parameters. Because radon has a relatively short half-life and decays to a solid particle, evaluations are typically performed for only the upper 15 feet of contaminated material. Each of the licensee's input values to the radon flux computer code for the contaminated materials and cover materials is discussed below.

The extension of the radon barrier will consist of a 0.3 m (1.0 foot)-thick compacted clay layer and will be overlain by a 1.4 m (4.5 foot)-thick frost protection layer. The radon barrier will be compacted to at least 90 percent maximum dry density (MDD) and will be taken from a local Cody shale layer. The frost and filter layer will be compacted to at least 95 percent MDD and will also be taken from local sources.

The licensee used the RADON computer code (NRC, 1989) to model the performance of the radon barrier flux. The RADON code is an interactive BASIC version of the FORTRAN computer program RAECOM, which is described in NUREG/CR–3533, Radon Attenuation Handbook for Uranium Tailing Cover Design (NRC, 1984). In 1989, the RAECOM code was modified by NRC to eliminate cost-benefit optimizing, and that code was named RADON, and its use is discussed in Regulatory Guide 3.64 (NRC, 1989). Both programs model radon flux using one dimensional, steady-state gas diffusion theory and are acceptable to determine compliance with the radon flux regulation.

3.2 Contaminated Material Parameters

The licensee performed sampling and testing to characterize the radium content and density of the tailings. The dry tailings density was determined from laboratory testing to be 1.43 g/cm$^2$. The radium concentration of the tailings (310 pCi/g) was calculated from the average grade of ore processed at the site (0.11 percent $U_3O_8$) using the appropriate formula from Regulatory Guide 3.64. This value was determined after operations had ceased at the site, and the ore grade did not vary significantly during operations. The licensee also sampled the tailings material to confirm that this value for the radium content of the tailings was reasonable and conservative and that areas in the tailings pile with a high concentration of slimes material would not lead to an unacceptably large radon flux from the pile. Based on a sampling of the tailings conducted in 1995 and 1996, the maximum average radium concentration of the thickest slimes deposits was 298 pCi/g, and the maximum average radium concentration of the other areas within the tailings pile was 215 pCi/g. Evaluation of the sampling results by NRC staff revealed that the largest concentration of radium generally occurred more than 3.0 m (10 feet) below the surface of the tailings. Also, the tailings are covered by a reclamation fill that varies from 0.6 m (2 feet) to over 9.2 m (30 feet) thick and that has a low radium concentration in comparison to the slimes material. This fill material was conservatively not included in the licensee's RADON code modeling. Based on these arguments, the NRC staff concludes that the value chosen for the radium concentration of the tailings is acceptable.

Based on default values from Regulatory Guide 3.64, the licensee used a value of 2.65 for the specific gravity of the tailings material, 5 m (16 feet) for the tailings thickness, 0.35 for the radon emanation coefficient, and 6 percent for the long-term water content of the tailings. The licensee used the values calculated by the RADON code for the tailings porosity (0.46) and diffusion coefficient (0.03887 cm$^2$/s). These values are acceptable and the NRC staff concludes that contaminated material parameters are conservative or are justified based on the site-specific measurements.

In addition to data from the Impoundment, the staff reviewed data obtained from within and below the remaining portion of the clay liners for the former north and south evaporation ponds. It was determined that the distinguishable 11(e).2 byproduct material had been removed and that the elevated radium and uranium below the pond areas were due to naturally radioactive soils and not due to products from the milling process.

### 3.3 Radon Barrier Properties

The radon barrier will consist of a 0.3 m (1 foot)-thick compacted clay layer covered by a 1.4 m (4.5 foot)-thick frost and filter layer. The source for the compacted clay material will be a local Cody shale, and the material for the frost and filter layer will be obtained from local materials similar to the existing cover.

The licensee has performed laboratory testing of the clay cover material and the average dry density of the material was determined from nuclear density and moisture test data to be 1.67 g/cm$^2$. Several samples of the clay cover material were tested for their maximum radium content, which was determined to be 3.6 pCi/g. This is the value for the radium content used in the RADON computer model for this layer. Several samples were also measured to determine emanation coefficient, and the maximum measured value of 0.23 was used for the modeling. The long-term moisture content for this layer was determined by using laboratory water retention tests. The average moisture content of the samples at a suction of 15 bar was taken as the lower bound of the long-term moisture content of the material and was measured to be 12.44 percent. The NRC staff concludes that these values are acceptable as site-specific measurements of the material properties.

The frost and filter layer was tested and the dry density measured at 95 percent of the Standard Proctor density was determined to be 1.78 g/cm$^2$. The material to be used for the frost and filter layer will also be tested during emplacement to ensure that the radium concentration does not exceed 10 pCi/g, which was the radium activity used in the RADON code model of the tailings cover. Several samples were measured for their emanation coefficient and the average emanation coefficient of these samples was determined to be 0.264. The long-term moisture content for this layer was measured by using laboratory water retention tests. The average moisture content of the samples at a suction of 15 bar was taken as the lower bound for the long-term moisture content of the material and was measured to be 11.48 percent. The NRC staff concludes that these values are acceptable as site-specific measurements of the material properties.

The licensee used the values calculated by the RADON code for the porosity and the diffusion coefficient for both layers of the radon barrier as shown in Table 5. The default value of the specific gravity of these materials was taken from Regulatory Guide 3.64 to be 2.65. The NRC staff finds the use of these values acceptable. The NRC staff concludes that radon barrier parameters are conservative or are justified based on the site-specific measurements.

Prior NRC staff evaluations of the frost and filter layer material for the heap leach disposal cell have determined that the frost penetration for this area will not exceed 4.5 feet (1.4 m) (NRC, 1998). Therefore, the proposed 4.5-foot-thick frost and filter layer is sufficient to protect the compacted clay layer from freeze-thaw effects, and it is acceptable for the licensee to assume that there is no freeze-thaw degradation of the clay layer. Also, the effects of biointrusion by animals or deep-rooted plants on the radon barrier layer have been minimized by the additional cover material and riprap, so it is acceptable for the licensee to not include degradation of the clay radon barrier by biointrusion in modeling the radon flux from of the tailings pile surface.

## 3.4 Radon Attenuation Modeling Results

Table 5 summarizes the RADON code input parameters used by the licensee. The radon flux from the area of the radon barrier extension was calculated to be 9.6 pCi/m$^2$s. During the review of the licensee's proposed extension of the radon barrier, it was determined that the original modeling of the existing radon barrier was not acceptable because of the use of several inappropriate values in the model. In response to an NRC request for additional information on this subject, Umetco repeated the analysis of the existing radon barrier on the main portion of the Impoundment, using appropriate values to demonstrate that the radon flux would be below 20 pCi/m$^2$s. The existing radon barrier was modeled using the same parameters as the proposed radon barrier extension, because the tailings material and the materials used to construct the radon cover are the same. The only difference between the two radon barrier areas is that the existing frost and filter layer is 2.6 m (8.5 feet) thick, whereas the radon barrier extension has a frost and filter layer that is only 1.4 m (4.5 feet) thick. With the revised modeling, the licensee calculated the radon flux above the existing radon barrier to be 5.3 pCi/m$^2$s.

**TABLE 5: Summary of the RADON Code Input Parameters for the License Amendment Request**

| RADON INPUT PARAMETERS | | | |
|---|---|---|---|
| **Layer** | **Tailings** | **Compacted Clay Layer** | **Frost and Filter Layer** |
| Radium Concentration (pCi/g) | 310 | 3.6 | 10 |
| Emanation Coefficient | 0.35 | 0.23 | 0.264 |
| Specific Gravity | 2.65 | 2.65 | 2.65 |
| Density (g/cm$^3$) | 1.43 | 1.67 | 1.78 |
| Porosity | 0.46 | 0.37 | 0.328 |
| Moisture Content (%) | 6 | 12.44 | 11.48 |
| Diffusion Coefficient (cm$^2$/sec) | 0.03887 | $8.044 \times 10^{-3}$ | $5.225 \times 10^{-3}$ |

Because modeling indicates that the average long-term radon flux should be less than 20 pCi/m$^2$s, the NRC staff concludes that there is reasonable assurance that the design meets the long-term radon flux criterion in 10 CFR Part 40, Appendix A, Criterion 6(1).

## 3.5 References

U.S. Nuclear Regulatory Commission (NRC), "Technical Evaluation Report for the Umetco Heap Leach Reclamation Plan," May 28, 1998.

--- "Final Standard Review Plan for the Review of a Remedial Action of Inactive Mill Tailings Sites under Title I of the Uranium Mill Tailings Radiation Control Act," Rev. 1, 1993.

---"Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers," Regulatory Guide 3.64, 1989.

---"Radon Attenuation Handbook for Uranium Mill Tailings Cover Design," NUREG/CR-3533, April 1984.

---"Final Environmental Statement, Related to Gas Hills Operations," NUREG-0702, July 1980.

RECOMMENDED LICENSE CHANGE:

The staff recommends that a change be made to Source Material License SUA-648, License Condition 54 to reflect the approval of the enhanced cover design for a portion of the above-grade tailings impoundment. The introductory paragraph of the license condition will now state:

> The final reclamation of the inactive above-grade tailings impoundment (includes experimental heap leach site) shall be in accordance with the December 18, 1980, Reclamation Plan and the April 19, 1979, and May 13, 1982, letters; except as superceded by the Design for Enhancement of the Previously Approved Reclamation Plan for the Above-Grade Inactive Tailings Design Report of October 6 and October 28, 1997, as modified by submittals dated May 22, June 26, July 20, July 28, September 8, September 15, and November 23, 1998, as well as April 9 and June 7, 1999.

ENVIRONMENTAL IMPACT EVALUATION:

During its review of the amendment request, the NRC staff performed an environmental assessment as required under 10 CFR Part 51.21for this licensing action because of the possibility of increased amounts of effluents (radioactive dust) that may be released offsite during the additional construction and because of the increased area to be disturbed. The requested licensing action does not meet any of the criteria in Part 51.20 requiring an environmental impact statement.

REFERENCES FOR THE ENHANCED DESIGN:

U.S. Nuclear Regulatory Commission (NRC), "Final Position on Review of Previously Approved Reclamation Plans," July 18, 1995.

---, letter to Umetco requesting radon attenuation model data, May 12, 1998.

---, letter to Umetco requesting additional information on surface water hydrology and radon attenuation aspects of the enhanced design, August 6, 1998.

---, letter to Umetco requesting additional information on geotechnical aspects of the enhanced design, August 19, 1998.

Shepherd Miller, Inc, transmittal to NRC of revised drawing 1 for the Response to Comments document, September 15, 1998.

Umetco, letter to NRC transmitting the Above-Grade Tailings Enhanced Reclamation Design, Part I, October 6, 1997.

Umetco, letter to NRC transmitting the Above-Grade Tailings Enhanced Reclamation Design, Parts II and III, October 28, 1997.

Umetco, letter to NRC transmitting the "Surety Cost Estimate," including revised amount for reclamation of the above-grade impoundment to reflect the enhanced design, March 9, 1998.

Umetco, letter to NRC transmitting the "Radon Attenuation Analysis," May 22, 1998.

Umetco, clarification of settlements values, June 26, 1998.

Umetco, letter to NRC informing staff that data on surface water hydrology was sent to the reviewer at Colorado State University, July 20, 1998.

Umetco, letter to NRC providing technical memorandum on slope stability and revised cover cracking analysis, July 28, 1998.

Umetco, letter to NRC transmitting the "Responses to NRC Review Comments," September 8, 1998.

Umetco, letter to NRC transmitting "Response to NRC Review Comments II," includes modifications to the enhanced design, November 23, 1998.

Umetco, letter to NRC transmitting page changes related to rock gradation, April 9, 1999.

Umetco, letter to NRC transmitting copy of 404 permit and drawing of revised design of the East Canyon Creek work area to allow re-establishment of wetlands, June 7, 1999.