January 26, 1996

MEMORANDUM TO: Joseph J. Holonich, Chief
HLUR/DWM/NMSS

FROM: Richard A. Weller, Acting Branch Chief /s/
ENGB/DWM/NMSS

SUBJECT: TECHNICAL EVALUATION REPORT FOR MEXICAN HAT AND MONUMENT VALLEY URANIUM MILL TAILINGS REMEDIAL ACTION PLAN

DOE submitted page changes on February 23, 1995, and on May 9, 1995, for the Final Remedial Action Plan for the co-disposal of the UMTRA Project Mexican Hat and Monument Valley mill tailings. The Surface Water and Erosion Protection Section (#4), and the Radon Attenuation and Site Cleanup Section (#6) for the Final Technical Evaluation Report (TER) are attached. The Geology and Geotechnical Stability Sections are near completion but finalization must await the receipt and acceptance of information from DOE.

In accordance with discussions with Bob Carlson, we are not providing references with each of the sections; references were provided in the draft submittal and have not changed.

If you have questions on this evaluation, please contact Elaine Brummett at 415-6606 or Ted Johnson at 415-6658.

Attachments: As stated

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Attachments

4.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

4.1 Hydrologic Description and Site Conceptual Design

DOE proposes to consolidate tailings from the Monument Valley and Mexican Hat tailings sites into a single pile at the Mexican Hat site. The Mexican Hat site is located approximately 8 miles north of the Utah-Arizona border and 2 miles southwest of Mexican Hat, Utah.

A small local drainage area exists upland of the site and will contribute flood flows which must be diverted around the disposal cell. Several well-entrenched gullies exist in the immediate site area upstream and downstream of the site. These gullies ultimately discharge into Gypsum Wash which in turn discharges into the San Juan River.

In order to comply with EPA standards that require stability of the tailings for 1,000 years to the extent reasonably achievable and, in any case, for at least 200 years, DOE proposes to stabilize the contaminated materials in an engineered embankment to protect them from flooding and erosion. The design basis events for design of the erosion protection included the Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF) events, both of which are considered to have low probabilities of occurrence during the 1000-year stabilization period.

As proposed by DOE, the tailings will be consolidated into a single pile which will be protected by a rock cover. The rock cover will have a slope of 2% on the top slopes and 20% on the side slopes. The remediated embankment will be surrounded by aprons which will safely convey flood runoff away from the tailings and prevent gully intrusion into the stabilized pile. In addition, interceptor ditches will be constructed to divert flood flows from the upland drainage area away from the disposal cell. Three natural gullies exist downstream of the disposal cell and will be protected from headward advancement by an engineered erosion protection design in each gully.

The upland area along the south edge of the embankment features several types of terrain, including short, steep (almost vertical) slopes and scattered small steep gullies. Some of these slopes have competent rock exposed on the surface; others are covered with fractured shale which may be susceptible to weathering and eventual erosion.

4.2 Flooding Determinations

The computation of peak flood discharges for various design features at the site was performed by DOE in several steps. These steps included: (1) selection of a design rainfall event; (2) determination of infiltration losses; (3) determination of times of concentration; (4) determination of appropriate rainfall distributions corresponding to the computed times of concentration; and (5) calculation of flood flows. Input parameters were derived from each of these steps and were then used to determine the peak flood discharges to be used in water surface profile modeling and in the final determination of rock sizes for erosion protection.

4.2.1 Selection of Design Rainfall Event

One of the most potentially disruptive phenomena that could affect long-term stability of the tailings pile is surface water erosion. DOE has recognized that it is very important to select an appropriately conservative rainfall event on which to base flood protection designs. DOE has concluded and the NRC staff concurs (NRC, 1990) that the selection of a design flood event should not be based on the extrapolation of limited historical flood data, due to the unknown level of accuracy associated with such extrapolations. Rather, DOE utilized the PMP, which is computed by deterministic methods (rather than statistical methods), and is based on site-specific hydrometeorological characteristics. The PMP has been defined as the most severe reasonably possible rainfall event that could occur as a result of a combination of the most severe meteorological conditions occurring over a watershed. No recurrence interval is normally assigned to the PMP; however, DOE and the NRC staff have concluded that the probability of such an event being equalled or exceeded during the 1000-year stability period is small. Therefore, the PMP is considered by the NRC staff to provide an acceptable design basis.

Prior to determining the runoff from the drainage basin, the flooding analysis requires the determination of PMP amounts for the specific site location. Techniques for determining the PMP have been developed for the entire United States primarily by the National Oceanographic and Atmospheric Administration in the form of hydrometeorological reports for specific regions. These techniques are widely used and provide straightforward procedures with minimal variability. The staff, therefore, concludes that use of these reports to derive PMP estimates is acceptable.

A PMP rainfall depth of approximately 8.1 inches in 1 hour was used by DOE to compute the PMF for the small drainage areas at the disposal site. This rainfall estimate was developed by DOE using Hydrometeorological Report (HMR) 49 (Department of Commerce, 1977). The staff performed an independent check of the PMP value, according to the procedures given in HMR 49. Based on this check of the rainfall computations, the staff concludes that the PMP was acceptably derived for this site.

4.2.2 Infiltration Losses

Determination of the peak runoff rate is dependent on the amount of precipitation that infiltrates into the ground during the occurrence of the rainfall. If the ground is saturated from previous rains, very little of the rainfall will infiltrate and most of it will become surface runoff. The loss rate is highly variable, depending on the vegetation and soil characteristics of the watershed. Typically, all runoff models incorporate a variable runoff coefficient or variable runoff rates. Commonly-used models, such as the Rational Formula (USBR, 1977), incorporate a runoff coefficient (C); a C value of 1 represents 100% runoff and no infiltration. Other models, such as the U.S. Army Corps of Engineers Flood Hydrograph Package HEC-1 (USACE), separately compute infiltration losses within a certain period of time to arrive at a runoff amount during that time period.

In computing the peak flow rate for the design of the rock riprap erosion protection at the proposed disposal site, DOE used the Rational Formula (Chow, 1959). In this formula, the runoff coefficient was assumed by DOE to be unity; that is, DOE assumed that no infiltration would occur. Based on a review of the computations, the staff concludes that this is a very conservative assumption and is, therefore, acceptable.

4.2.3 Time of Concentration

The time of concentration is the amount of time required for runoff to reach the outlet of a drainage basin from the most remote point in that basin. The peak runoff for a given drainage basin is inversely proportional to the time of concentration. If the time of concentration is computed to be small, the peak discharge will be conservatively large. Times of concentration and/or lag times are typically computed using empirical relationships such as those developed by Federal agencies (USBR, 1977). Velocity-based approaches are also used when accurate estimates are needed. Such approaches rely on estimates of actual flow velocities to determine the time of concentration of a drainage basin.

The times of concentration for the riprap design were estimated by DOE using the Kirpich Method (USBR, 1977) and the Manning's Equation (Chow, 1959) which estimates actual flow velocities. Such velocity-based methods are considered by the staff to be appropriate for estimating times of concentration. Based on the precision and conservatism associated with such methods, the staff concludes that the times of concentration have been acceptably derived. The staff further concludes that the procedures used for computing time of concentration are representative of the small steep drainage areas present at the site.

4.2.4 Rainfall Distributions

After the PMP is determined, it is necessary to determine the rainfall intensities corresponding to shorter rainfall durations and times of concentration. A typical PMP value is derived for periods of about 1 hour. If the time of concentration is less than 1 hour, it is necessary to extrapolate the data presented in the various hydrometeorological reports to shorter time periods. DOE utilized a procedure recommended in HMR 49 and by the NRC staff (NRC, 1990). This procedure involves the determination of rainfall amounts as a percentage of the 1-hour PMP and computes rainfall amounts and intensities for very short periods of time. DOE and the NRC staff have concluded that this procedure is conservative.

In the determination of peak flood flows, PMP rainfall intensities were derived by DOE as follows:

Rainfall Duration (minutes)	Rainfall Intensity (inches/hr)
2.5	53
5	44
15	24
60	8.1

The staff checked the rainfall intensities for the short durations associated with small drainage basins. Based on a review of this aspect of the flooding determination, the staff concludes that the computed peak rainfall intensities are conservative.

4.2.5 Computation of PMF

4.2.5.1 Top and Side Slopes

The PMF was estimated for the top and side slopes using the Rational Formula (Chow, 1959) which provides a standard method for estimating flood discharges for small drainage areas. For a maximum top slope length of 1420 feet, DOE estimated the peak flow rate to be approximately 0.9 cubic feet per second per foot of width (cfs/ft). For a maximum combined top and side slope length of 1520 feet, the peak flow rate for the side slope was estimated by DOE to be about 1.0 cfs/ft. Based on staff review of the calculations, including the rainfall intensities and times of concentration, these estimates are considered to be acceptable.

4.2.5.2 Apron/Toe

4.2.5.2.1 Downstream Apron/Toe

The PMF flow rate for the downstream apron was computed similarly to the design flow rate for the top and side slopes. As discussed above, the flow rate was computed for the maximum slope length and is considered to be acceptable.

Further, DOE considered that the downstream apron/toe area on the southeast side of the disposal cell may be subject to concentrated flows directly along its length. Because there is a potential for flood flows to occur in a northeasterly direction in this area and for those flows to concentrate along the edge of the toe, DOE estimated the flow rates in this area and designed the toe for such an occurrence. Based on review of the peak flow rates and other calculations associated with the design, the staff concludes that the flow estimates are acceptable.

4.2.5.2.2 Upstream Apron

DOE computed peak PMF flow rates for the upstream apron using assumptions of concentrated sheet flow. Based on the topography immediately upstream of the cell, DOE concluded that several existing natural gullies may further concentrate flood flows and produce grea er peak PMF flow rates than sheet flow. Because the shear stresses produced in a gully are likely to exceed the flow depths produced by uniform flow spreading across a plane surface, DOE considered natural gullies in the analysis.

The design of the apron is similar to the design of the upstream apron at the Lowman site where various factors were addressed, including the extent of energy dissipation, hydraulic jumps, flow velocities, and flow spreading. Based on a review of the detailed calculations and the design, the flow rates are considered to be acceptable.

4.2.5.3 Permanent Interceptor Ditches

The ditch layout is such that upland surface runoff will be diverted through several diversion and interceptor ditches. In the PMF analysis, the Rational Formula was used to compute peak flow rates at different locations in the ditches. Maximum flow rates were estimated for each of the ditches. Based on a check of the calculations of drainage area, time of concentration, and rainfall intensity, the staff concludes that the PMF estimates for the ditches are acceptable.

4.2.5.4 Downstream Gullies

Surface runoff from the pile and off-site will be concentrated into three separate gullies downstream of the cell. Using methods similar to those discussed above, DOE computed peak PMF flow rates of 689, 566, and 435 cfs for gullies 1,2 and 3, respectively. Based on staff review of the calculations, the estimates are considered to be acceptable.

4.3 Water Surface Profiles and Channel Velocities

Following the determination of the peak flood discharges, it is necessary to determine the resulting water levels, velocities, and shear stresses associated with those discharges. These parameters then provide the basis for the determination of the required riprap size and layer thickness needed to ensure stability during the occurrence of the design event.

4.3.1 Top and Side Slopes

In determining riprap requirements for the top and side slopes, DOE utilized the Safety Factors Method (Stevens, et al., 1976) and the Stephenson Method (Stephenson, 1979), respectively. The Safety Factors Method is used for relatively flat slopes of less than 10 percent; the Stephenson Method is used for slopes greater than 10 percent. The validity of these design approaches has been verified by the NRC staff through the use of flume tests at Colorado State University. It was determined that the selection of an appropriate design procedure depends on the magnitude of the slope (Abt, et al., 1987). The staff, therefore, concludes that the procedures and design approaches used by DOE are acceptable and reflect state-of-the-art methods for designing riprap erosion protection.

4.3.2 Apron/Toe

4.3.2.1 Downstream Apron/Toe

The design of the apron at the toe of the disposal cell is based on the fact that it will be keyed into competent bedrock layers. DOE provided information to show that competent bedrock layers exist in all of the toe areas. DOE provided toe designs which extend to at least the depth of competent rock. Further, to provide information to document the extent and adequacy of the bedrock layer, DOE performed a field verification program that identified these layers and their long-term erosion resistance capability.

The staff was present during construction and witnessed DOE's field verification program of rock competency. Based on these observations and information provided by DOE, the staff concludes that the designs are acceptable.

4.3.2.2 Upstream Apron

The design of the upstream apron is considered to be adequate, as discussed in Section 4.2.5.2, above. DOE used criteria recommended by NRC staff (NRC, 1990) to design the rock. Additional information may be found in Section 4.4 below.

4.3.3 Permanent Interceptor Ditches

Manning's Equation (Chow, 1959) was used to estimate normal depths and velocities under the estimated discharge conditions. This method is considered by the staff to be acceptable for determining flow conditions for diversion channels of relatively uniform slope and cross-section.

4.3.4 Downstream Gullies

Water surface profiles and flow velocities for the downstream gullies were determined similarly to those determined for the interceptor ditches. Based on a review of the calculations, the staff considers that the profiles and velocities have been acceptably derived. Additional discussion may be found in Section 4.4 below.

4.4 Erosion Protection

4.4.1 Sizing of Erosion Protection

Riprap layers of various sizes and thicknesses are proposed for use at the Mexican Hat site. The design of each layer is dependent on its location and purpose.

4.4.1.1 Top Slopes and Side Slopes

The layer of riprap on the top slope has been sized to withstand the erosive velocities resulting from an on-pile PMP, as discussed above. DOE proposes to use a 1-foot-thick layer of Type A rounded rock with a minimum D_{50} of 1.7 inches. The riprap will be placed on a 6-inch-thick bedding layer. The Safety Factor Method was used to determine the rock size. In some areas of the top slope, DOE used Type B1 rock which has a minimum D_{50} of 3.0 inches. The use of Type B1 was necessitated because of a shortage Type A rock. The use of this larger rock is acceptable.

The rock layer on the side slopes is also designed for an occurrence of the local PMP. DOE proposes to use a 1-foot-thick layer of Type B rounded rock with a minimum D_{50} of approximately 4.4 inches. The rock layer will be placed on a 6-inch-thick bedding layer. Stephenson's Method was used to determine the required rock size. Appropriate values were used for the specific gravity of the rock, the rock angle of internal friction, and porosity.

Based on staff review of the DOE analyses and the acceptability of using appropriate design methods, as discussed in Section 4.3 above, the staff concludes that the proposed rock sizes are adequate.

4.4.1.2 Apron/Toe

As discussed above, the downstream apron/toe will be keyed into competent bedrock. Because the bedrock has been verified to be competent, such designs will prevent headward erosion into the cell area.

The upstream apron will be about 10 feet wide and will consist of both Type B and Type B1 rock, depending on the area of placement. Based on staff review of calculations and design methods for the aprons, the designs are considered to be acceptable.

4.4.1.3 Interceptor Ditches

The Safety Factors Method was used to determine rock sizes in the main channel and outlet sections of the west ditch. Type C riprap with a minimum D_{50} rock size of about 7 inches will be placed in the ditch channel and outlet. As previously discussed, the staff concludes that use of the Safety Factors Method is acceptable.

DOE provided justification for the proposed ditch designs and analyzed the design of the interceptor ditches in several areas. DOE also provided design details and computations for the ditch side slopes and considered the effects of PMF flows directly down the proposed side slopes from the upland drainage areas. DOE indicated that the ditch side slopes will be keyed into the competent rock layers. Also, analyses were provided to assess the potential for flow concentrations to occur where flows from natural gullies enter the ditches in a direction perpendicular to the flow of the ditch.

Additionally, the ditch outlets will be keyed into competent bedrock layers. As discussed above, DOE has satisfactorily documented the adequacy of these rock layers through field verification programs.

Further, DOE considers that sediment from the upland drainage areas is not expected to clog the diversion ditches because significant erosion has already occurred leaving the bedrock exposed. DOE also provided analyses to document that sediment will not be a problem. These analyses indicate that the ditches are designed to accommodate or flush the sediment.

Based on a review of the calculations and the information provided, the staff concludes that the ditches have been acceptably designed.

4.4.1.4 Downstream Gullies

DOE designed the riprap for the downstream gullies similar to the riprap for the diversion ditches. Based on staff review of the analyses provided by DOE, the staff considers the design to be acceptable.

The outlets of the gullies will be keyed into competent rock. As discussed above, the staff concludes that the competency and areal extent of these rock layers are acceptable.

4.4.2 Rock Durability

The EPA standards 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 report examined the ability of the erosion protection to withstand flooding events reasonably expected to occur in 1000 years. The durability of the rock used for erosion protection needs to be sufficient to provide adequate rock sizes over the long-term.

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.

DOE conducted investigations to identify acceptable sources of rock in the site vicinity. The suitability of the rock as a protective cover was then assessed by laboratory tests to determine its physical characteristics. DOE conducted the tests and used the results of these tests to classify the rock's quality and to assess the expected long-term performance of the rock. In accordance with past DOE rock-testing practice, the tests included:

1. Petrographic Examination (ASTM C295). Petrographic examination of rock is used to determine its physical and chemical properties. The examination establishes if the rock contains chemically unstable minerals or volumetrically unstable materials.

2. Bulk Specific Gravity (ASTM C127). The specific gravity of a rock is an indicator of its strength or durability; in general, the higher the specific gravity, the better the quality of the rock.

3. Absorption (ASTM C127). A low absorption is a desirable property and indicates resistance to disintegration of the rock by salt action and mineral hydration.

4. Sulfate Soundness (ASTM C88). In locations subject to freezing or exposure to salt water, a low percentage is desirable.

5. Schmidt Rebound Hammer. This test measures the hardness of a rock and can be used in either the field or the laboratory.

6. Los Angeles Abrasion (ASTM C131 or C535). This test is a measure of rock's resistance to abrasion.

7. Tensile Strength (ASTM D3967 or ISRM Method). This test is an indirect test of a rock's tensile strength.

DOE then used a step-by-step procedure for evaluating durability of the rock, in accordance with procedures recommended by the NRC staff (NRC, 1990), as follows:

Step 1. Test results from representative samples are scored on a scale of 0 to 10. Results of 8 to 10 are considered "good"; results of 5 to 8 are considered "fair"; and results of 0 to 5 are considered "poor".

Step 2. The score is multiplied by a weighting factor. The effect of the weighting factor is to focus the scoring on those tests that are the most applicable for the particular rock type being tested.

Step 3. The weighted scores are totaled, divided by the maximum possible score, and multiplied by 100 to determine the rating.

Step 4. The rock quality scores are then compared to the criteria which determines its acceptability, as defined in the NRC scoring procedures.

DOE proposes that Type A and Type B rock for the Mexican Hat site will be produced from the Bluff Quarry and that Type C rock will be produced from the Sugarloaf Quarry. Using the scoring procedures discussed above, DOE determined that the rock will meet NRC criteria. Based on site visits to the quarries and review of the durability tests and scoring calculations, the staff concludes that these rock types will be of sufficient quality to meet EPA standards.

4.4.3 Testing and Inspection of Erosion Protection

The staff has reviewed and evaluated the testing and inspection quality control requirements for the erosion protection materials. Based on a review of the information provided in the RAIP, the staff concludes that the proposed testing program is acceptable.

4.5 Upstream Dam Failures

There are no impoundments near the site whose failure could potentially affect the site.

4.6 Conclusions

Based on its review of the information submitted by DOE, the staff concludes that the site design meets EPA requirements as stated in 40 CFR 192 with regard to flood design measures and erosion protection. The staff concludes that an adequate hydraulic design has been provided to reasonably assure stability of the contaminated material for a period of 1000 years, or in any case, at least 200 years.

6.0 RADON ATTENUATION AND SITE CLEANUP

6.1 Introduction

This section of the TER documents the staff evaluation of the radon attenuation design, the processing site cleanup plan, and the radiation verification plan for the co-disposal of uranium mill tailings from the Mexican Hat, Utah, and Monument Valley, Arizona, UMTRA Project sites at the Mexican Hat site. The DOE Final RAP dated February 1993, was supplemented with additional information dated July 13, 1993, July 20, 1994, and February 23, 1995. The NRC review focuses on the radon attenuation design, radiological cleanup, and verification aspects of the proposed remedial action to ensure compliance with the EPA standards. The NRC staff's review is in accordance with the guidance in the NRC Standard Review Plan (NRC, 1993).

6.2 Radon Attenuation

The proposed remedial action involves the consolidation of contaminated materials from the Mexican Hat (HAT) site into a single pile on site. In addition, contaminated materials from the Monument Valley (MON) site will be relocated to the HAT site and placed on top of the HAT materials. The contaminated materials will then be capped by a 2-foot-thick soil plus bentonite (10 percent by weight) layer that forms a radon barrier. This barrier is designed to reduce radon (Rn-222) diffusion rates, thereby attenuating radon flux to levels at or below the EPA standard (20 pCi/m^2s) for the release of radon to the atmosphere from residual radioactive materials.

NRC staff review of the cover design for radon attenuation included evaluation of the other layers of the cover (6-inch filter/bedding and 8 or 12-inch small rock erosion protection) for their ability to protect the radon barrier layer from drying and disruption by considering the long-term effects of erosion (TER Section 4), freeze-thaw damage, and biointrusion. Staff also considered that the barrier layer thickness is designed to satisfy criteria for construction, settlement, cracking, and infiltration of surface water. These aspects of cell design are discussed in detail in Section 3 of this TER.

Finally, staff evaluated the DOE radon flux model and parameter (input) values and subsequently performed an independent analysis of the model using the RADON computer code (NRC, 1989). Each of these evaluations and analyses are discussed below.

6.2.1 Parameter Value Evaluation

The thickness of the radon barrier required to limit the radon flux depends on the physical and radiological properties of the radon barrier soil and of the contaminated materials. These properties and their effects on radon movement are reflected in the parameter values and calculations of the RAECOM/RADON computer code. These properties (parameters) include: material thickness, density, porosity, long-term moisture content, and radon diffusion coefficient. In addition, radium (Ra-226) activity concentration, radon emanation fraction, and placement sequence of the various types of contaminated materials are parameters of the radon flux model. NRC staff evaluated the justification and assumptions made for each parameter value to confirm that each value was representative of the material or conservative, consistent with anticipated construction specifications, and was based on long-term conditions (at least 200 years).

The sampling and testing methods for the materials were also evaluated for their appropriateness and their ability to ensure that there was sufficient data to provide for a robust analysis. In addition, the model was compared to the disposal cell design and the construction specifications to ensure compatibility.

The staff's findings regarding the adequacy of the data supporting the input parameter values to the radon flux model for the contaminated and radon barrier materials are described below.

6.2.1.1 Contaminated Material

Contaminated HAT materials are: 1) the lower tailings pile (stabilized in-place); 2) the upper tailings pile (placed on top of the lower tailings pile); and 3) the off-pile material, which includes both windblown and waterborne material (placed over the relocated upper tailings pile and on cell side slopes).

Contaminated MOM materials, in order of proposed placement on the HAT tailings, are: 1) material from the heap leach pads; 2) new pile tailings; and 3) windblown and waterborne materials (areas A-E and roads). A small amount of pond material, with the higher Ra-226 concentrations, was placed first. The HAT materials are mainly tailings slimes and sand-slimes and the MOM materials are predominately sand tailings (lower Ra-226 concentration).

HAT Materials

DOE has estimated that the lower tailings pile is approximately 24 feet in depth. It is located in a wash with a clean-fill dike across the northern side of the pile. DOE has indicated that the average combined thickness for the relocated upper tailings pile and off-pile material is 10 feet with approximately 30 percent of this due to windblown/waterborne material.

DOE based the upper and lower pile tailings dry density parameter values on test results from three samples each (compacted to about 90 percent). The lower pile tailings dry density averaged 1.54 g/cm^3 with a specific gravity of 2.79. The upper pile tailings dry density averaged 1.76 g/cm^3, and the specific gravity was 2.82. The calculated porosity was 0.51 and 0.45, respectively. One sample of off-pile material was tested yielding a dry density value of 1.68 g/cm^3 and specific gravity of 2.71, resulting in a porosity of 0.38. DOE's density measurements made during placement of the relocated upper pile and off-pile materials demonstrated that the average dry density is 1.75 g/cm^3 (over 1300 samples) and 1.84 g/cm^3 (144 samples), respectively (calculation 9-421-03-00). These latter values and the corresponding porosity values are more representative because of the large sample size and they were used by DOE in the RAECOM analysis.

Long-term moisture values for the HAT materials were determined by capillary moisture tests, the Rawls and Brakensiek equation, and the empirical methodology suggested by Rogers in NUREG/CR-3533 (NRC, 1984). DOE selected the results of the capillary testing as being representative because it is the only method of the three that is not empirical in nature. Four tests each were performed on undisturbed samples and two each on compacted samples from the lower and upper pile materials yielding values of 25 and 13.6 percent moisture by weight, respectively. The long-term moisture content value for off-pile materials was based on one test of a compacted sample. DOE considered the test result of 5.6 percent acceptable for the model, because the placement moisture of the material was to be around 10 percent. However, moisture test results of 144 samples of as-placed material averaged 6.9 percent. Staff considers that the moisture values for the lower and upper tailings are acceptable, but that a value of approximately 5.0 percent should be used for the off-pile material.

The radon emanation fraction values of the contaminated materials at HAT were derived from the average test results of representative samples. DOE's tests indicated emanation fractions of 0.17 (8 test pits, 23 samples) and 0.19 (6 test pits, 18 samples) for the lower and upper tailings, respectively, with moisture content between 10 and 10.5 percent. Because the emanation fraction can vary with moisture and considering the expected long-term moisture content, DOE used the conservative value of 0.25 in the model for both the lower and upper pile materials. No emanation tests were performed for off-pile materials. Instead, DOE assigned a value of 0.18, the average of the upper and lower piles measured values, on the basis that off-pile materials would have similar characteristics to the piles from which the material originated. Staff considers that off-pile materials are wind or waterborne and would represent the finer fraction of the tailings, therefore, average tailings values should not be assumed for off-pile material. For example, DOE used an emanation value of 0.45 (more conservative than the code default value) for the Rifle off-pile materials. Because test data are not available, staff considers that DOE should use the code default value of 0.35 for the emanation fraction for the off-pile material.

The average measured Ra-226 values for the lower and upper pile material were 763 pCi/g and 624 pCi/g, respectively. DOE estimated the Ra-226 activity for some areas of off-pile material. DOE stated that the most radioactive off-pile material (from Area #10, 500 pCi/g) will be placed beneath the rest of the off-pile material, thus the bulk of the HAT off-pile material will have an activity of 45 pCi/g and the 58.7 pCi/g value used in the model is conservative. DOE stated that relocated HAT material placed in the upper 10 feet of the side slopes contains 1.6 to 38 pCi/g of Ra-226 and the lower 10 feet of material contains 77 to 215 pCi/g. The number of samples and average values were not indicated (calculation 9-239-05-03, sheet 6), however, staff considers that there is sufficient data to conclude that the flux model Ra-226 values are acceptable.

The radon diffusion coefficient values were determined from three samples each of the upper and lower pile tailings at 90 percent compaction. The best fit curve (LSDFIT correlation) of the diffusion coefficient versus moisture saturation indicates values of 0.0035 and 0.015 cm^2/s for the lower and upper pile materials at the long-term moisture content, respectively. A diffusion coefficient of 0.0295 cm^2/s was calculated for the off-pile materials using the equation presented in NUREG/CR-3533. One sample was tested and yielded a value of 0.035 cm^2/s, but DOE considered the result unreliable (without explanation). Staff considers that although reliable test results are preferred, the calculated radon diffusion coefficient value for off-pile material is acceptable for preliminary design. Measured values should be used in the final radon flux analysis.

MON Materials

DOE predicted MON contaminated material thicknesses in the cell of 5 feet for the heap leach pad material, 14 feet for new pile material, and 1 foot for off-pile material, with placement in the pile in that order. Tailings from the MON site were reprocessed so they are sandy and contain low levels of Ra-226. DOE indicated that because the MON material, with low radon emanation, will be placed only on the top of the cell, the side slope model governs the thickness of the radon barrier. Therefore, the parameter values for the MON materials are not critical for determining the radon barrier thickness and limited testing of these materials was performed. Staff confirmed this conclusion by modeling conservative parameters values for the MON materials as discussed in Section 6.2.2.

Most parameter values for the heap leach and new pile materials were based on tests results from one sample. The dry density at placement compaction and the specific gravity were measured on the same sample used for the diffusion coefficient determination. The heap leach sample had a dry density of 1.78 g/cm^3 and a specific gravity of 2.78. The new pile sample had a dry density of 1.54 g/cm^3 and a specific gravity of 2.67. Porosities were then calculated to be 0.36 and 0.43, respectively. DOE assumed that the off-pile (primarily windblown) material would be physically similar to the heap leach material and assigned the off-pile materials the same values for density, porosity, emanation fraction, and diffusion coefficient as the heap leach material. Although staff considers values based on such limited data unacceptable, DOE will not use the results of the top slope flux model to determine the radon barrier thickness. Therefore, staff does not object to using these values for estimating the top slope radon flux.

For the long-term moisture content value, DOE used the measured 5 percent ambient moisture for the heap leach pads, conservatively estimated 2 percent for the new pile material, and used 5 percent for the off-pile materials (measured 10 percent in-situ). Staff considers that the values chosen are adequately conservative.

DOE's emanation fraction values were the average test results of 5 samples from the heap leach pads and 15 from the new pile, resulting in values of 0.29 and 0.26, respectively. All measurements "were made at the ambient moisture content of each sample, which generally averaged approximately five percent (dry weight basis)."

The volume-weighted average Ra-226 concentration in MON contaminated materials was based on 403 samples (calculation 19-332-01-00). The heap leach pads material contains approximately 51.2 pCi/g, the new pile areas 46.7 pCi/g, and the off-pile areas 56.9 pCi/g of Ra-226. Staff considers that the Ra-226 values are acceptable as preliminary estimates. Final values will be derived through the standard DOE procedure of sampling for Ra-226 analyses after placement of contaminated material in the cell.

The measured radon diffusion coefficient values for the new pile and heap leach pads materials were 0.048 and 0.029 cm^2/s, respectively. One sample of each material was measured at three different moisture values. A best fit curve (LSDFIT correlation) of the diffusion coefficient versus moisture saturation data was used to indicate the diffusion coefficient at the long-term moisture value. DOE's "worst case" model used 0.04 cm^2/s for the heap leach and off-pile materials to be conservative and this is acceptable to staff.

DOE's standard procedure is to use test values obtained from the placed material in the final RAECOM analysis. That analysis should be presented in the Completion Report to substantiate that the as-built cell will meet the long-term radon flux standard.

6.2.1.2 Radon Barrier Soil

DOE determined the physical parameters for the radon barrier based on tests of soil amended with various percentages of bentonite. Two sources of bentonite were evaluated: bentonite from Redmund Clay and Salt Co., Utah (RED bentonite) and from Wyo-Ben Inc., Montana (WYO bentonite). For the radon barrier design, DOE modeled the test results from the 7 percent and 12 percent RED bentonite barrier soils. Because the RAP design calls for 10 percent RED bentonite, flux estimates from modeling the two bentonite concentrations were interpolated to arrive at the estimated radon flux from the barrier with 10 percent bentonite.

The measured specific gravity was 2.62 and 2.63, and the dry density was 1.92 and 1.90 g/cm^3 for the 7 and 12 percent bentonite mixtures (5 and 13 samples), respectively. Dry density was taken as 100 percent maximum Proctor density (ASTM D698), the compaction at which the radon barrier is to be placed. The results were used to calculate porosities of 0.29 and 0.27 for the bentonite amended soils.

DOE considered both natural moisture content and 15-bar moisture content in their determination of the long-term moisture content of the unamended soil. For the amended materials, only 15-bar moisture contents were considered. These long-term values are 7.64 and 9.55 percent for the 7 and 12 percent bentonite amended soils, respectively. DOE performed radon diffusion tests for each of the two bentonite mixtures (5 and 24 samples, respectively) at various moisture levels. Values corresponding to the long-term moisture values (0.0096 and 0.0078 cm^2/s) were then taken from the data plot of saturation versus diffusion coefficient.

NRC staff considers that adequate testing was performed, and that conservative moisture values were chosen for the radon barrier soils. Although not a concern at this time, Ra-226 values for the barrier soil were not found in the

RAP. These values should be presented in the Completion Report to confirm that the average value approximates background levels.

6.2.2 Evaluation of Radon Attenuation Modeling

The RAP does not contain a separate discussion of the radon attenuation model. However, NRC staff was able to evaluate the model based on information from various RAP calculations, draft RAPs, and DOE submittals in response to open issues.

DOE used the RAECOM computer code to derive the barrier thickness required to meet the radon flux standard, and to calculate the estimated radon flux from the proposed radon barrier. Because DOE has chosen the RED bentonite mixed at 10 percent dry weight with soil for radon barrier design and construction, the flux value was interpolated from the 7 and 12 percent bentonite RAECOM models.

DOE modeled both the top slope and side slopes. The top slope was modeled with the anticipated 20 feet of MON materials. To be conservative, DOE modeled the side slope with the contaminated material consisting of 10 feet of lower pile HAT tailings (highest Ra-226 value) covered with 10 feet of HAT off-pile materials. This is different from how the cell will actually be construction with HAT upper pile tailings between the lower pile and off-pile materials, and portions of the side slopes containing clean material. According to drawings and cross-sectional sketches, the north and east side slopes consist of at least 10 feet of uncontaminated soil between the HAT tailings and the HAT off-pile material. There is no south side slope, as the tailings rest against the natural slope of the ground. Therefore, the side slope model is conservative for radon flux estimation (i.e., results in a higher than expected flux).

DOE indicated that modeling the average parameter values results in a 21.3-inch radon barrier (containino 10 percent bentonite) thickness required to meet the flux standard on the side slope and 9.2 inches required for the top slope. DOE also calculated a standard error of the mean (SEM) on the few parameter values that had enough data points. Then the parameters values, plus or minus the SEM, whichever is conservative, were used in the model (calculation 9-421-03-00). These "worst case" values resulted in a required barrier thickness of 24.7 inches for the side slope.

NRC staff performed an independent analysis using the RADON computer code to model the radon flux. Conservative parameter values were used where test data were limited or non-existent. The values for the radon barrier soil were selected based on the specifications of materials designated for radon barrier. The side slope model used the expected layer sequence, as reflected in the DOE cross-sectional sketches (February 1995, submittal). The small area expected to have the highest flux rate (area of sections 16 and 17) was estimated to have a flux of 26.2 $pCi/m^2/s$, with the majority of the side slopes having a flux of 12 $pCi/m^2/s$. The conservative analysis for the top slope resulted in a radon flux of 10.4 $pCi/m^2/s$. Therefore, the cell average long-term radon flux would be less than 13 $pCi/m^2/s$ and confirms DOE's analysis that the flux would be lower than the standard of 20 $pCi/m^2/s$.

NRC staff also evaluated DOE's analysis of frost penetration and the possible effect of biointrusion on the radon barrier. DOE indicated (calculation 9-420-03-00) that the worst frost penetration in the cell cover would be 22.9 inches for the side slope and 21.7 inches for the top slope. DOE's modeling conservatively assumed a lack of snow cover, and that the radon barrier would be saturated at the time of freezing and, thus, susceptible to cracking due to the formation of ice lenses. DOE modeled the freeze-thaw damage effect on radon attenuation of the barrier soil in response to a previously identified open issue. The results indicated that there would not be a significant effect on the radon flux estimate. NRC staff performed an analysis using a different model (conservative emanation fraction for the HAT material with 11 percent increase in barrier porosity with code-calculated density and diffusion coefficient) and concludes that some areas of the side slopes could exceed the radon flux limit after freeze-thaw damage. However, staff concludes that the average cell cover radon flux would not exceed the limit after expected freeze-thaw damage, therefore, DOE's conclusion is acceptable.

The long-term effect of biointrusion on the radon barrier was not specifically addressed in the RAP. NRC staff determined that the 8 to 12-inch rock cover and 6-inch drain/filter layer in the semi-arid climate should discourage most deep-rooted plants and burrowing animals from establishing themselves in the cover. Because of this and the low estimated long-term radon flux, potential damage to the radon barrier (increased porosity and decreased density) from biointrusion was not modeled.

In conclusion, NRC staff considers that although some parameters of the DOE radon flux model are estimated values that are not conservative, considering that other very conservative model assumptions were used, there is reasonable assurance that the design radon barrier thickness will limit the long-term radon flux sufficiently to meet the flux standard. However, the Completion Report should contain the final RAECOM analysis that reflects the as-built condition. DOE should also provide the radon flux measurement data to allow for confirmation that the design is adequate.

6.3 Site Clean-Up

Field sampling and radiological surveys identified approximately 2,800,000 cubic yards (cy) of contaminated material at the HAT site and an estimated 1,100,000 cy of contaminated material at the MON site that will be stabilized at the HAT processing site.

Two buildings remain at the HAT processing site. DOE indicated that the former sheet metal shop and health clinic were previously decontaminated and acceptable radiation levels were measured. However, the radiological data for the two buildings should be provided for review or incorporated into the Completion Report.

Background soil Ra-226 levels at the HAT and MON sites average 1.1 and 1.0 pCi/g, respectively. The method for determination of background radionuclide level is acceptable to NRC staff.

6.3.2 Clean-Up Standards

DOE has committed to excavate contaminated areas to meet the EPA standards for Ra-226 in soil, and to place the contaminated materials in an engineered disposal cell. Excavation will be monitored to ensure that cleanup efforts are complete. The surface will be restored to a grade that controls surface drainage.

DOE will excavate Th-230 to a 1000-year bulk (corrected for percent cobbles) Ra-226 concentration. If elevated Th-230 levels extend into groundwater, excavation will continue if water pumping or other controls are reasonable. In any case, Th-230 will be removed to as low a level as is reasonably achievable (RAP, Appendix C). This approach is acceptable to staff.

6.3.3 Verification

The final radiological verification survey for land cleanup will be based on 100-square-meter areas. DOE may use a variety of measurement techniques, depending on particular circumstances. The standard method for Ra-226 verification is analysis of composite soil samples, by gamma spectrometry.

Verification for Th-230 wil' be performed in all grids suspected of having a mechanism to preferentially mobilize Th-230 over Ra-226 and in 10 percent of the subpile grids. If any verification grid contains elevated Th-230, samples from adjacent grids will also be analyzed for Th-230.

After the radon barrier is placed on the cell, DOE will perform radon flux measurements to ensure that the average rate is less than 20 pCi/m^2/s.

6.4 Conclusions

Based on review of the radon attenuation design for the Hat disposal cell, as presented in the final RAP and supporting documents, NRC staff concludes that the radon barrier, as designed, should meet the EPA long-term radon flux standards. However, DOE should provide the final RAECOM analysis that reflects the as-built condition of the disposal cell and the flux measurement data in the Completion Report to confirm that there is reasonable assurance that the long-term design is adequate.

Staff considers that the radiological characterization program, the proposed processing site cleanup, and the radiological cleanup verification plan are acceptable, as they should result in the site meeting the EPA soil cleanup standards. However, DOE should provide the radiological data for the two on-site buildings (former clinic and sheet metal shop) or summarize the data in the Completion Report to document that remedial action by the UMTRA Project was not required.