TECHNICAL EVALUATION REPORT

FOR THE TAILINGS CELL 2 EXPANSION RECLAMATION PLAN
RIO ALGOM MINING LLC'S URANIUM MILL FACILITY,
AMBROSIA LAKE, NEW MEXICO

U.S. Nuclear Regulatory Commission
Office of Federal and State Materials and Environmental Management Programs
Division of Waste Management and Environmental Protection

License SUA-1473

Docket 40-8905

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1.0 INTRODUCTION

1.1 Summary

In April 2005, Rio Algom Mining Limited Liability Corporation (Rio Algom) sent) a Reclamation Plan amendment request for disposal of its evaporation pond sediments at the Ambrosia Lake uranium mill tailings facility (Rio Algom, 2005) to the U.S. Nuclear Regulatory Commission (NRC). In a followup to the initial proposed plan, Rio Algom submitted, in a letter dated May 31, 2007, a Revision 1 of the plan, and a response to an NRC request for additional information (Rio Algom, 2007a).

The plan addresses the design, methods, and procedures to be implemented to ensure that evaporation pond materials are disposed of in the reclaimed tailings pile in a manner that is protective of human health and the environment and in accordance with the Uranium Mill Tailings Radiation Control Act, as amended, and regulations in Title 10 of the Code of Federal Regulations, Part 40 (10 CFR Part 40). Sections 2, 3, and 4 of this document address the NRC staff's review of the technical aspects of the proposed plan, and provide conclusions with respect to meeting NRC regulatory requirements. An Environmental Assessment also has been prepared for this action. It resulted in a Finding of No Significant Impact (FONSI) which was published in the *Federal Register* on November 13, 2007 (72 FR 63934).

1.2 Background

The Ambrosia Lake site is in the Ambrosia Lake mining district of New Mexico, 25 miles north of Grants, New Mexico. Rio Algom began processing ore in 1958, and processed approximately 33 million tons of ore through 1985. In 1989, reclamation of the tailings facilities commenced with work on the top surface of the largest tailings impoundment. Reclamation activities have, at times, included excavation and disposal of unlined evaporation pond residues, contaminated soil cleanup, reclamation of the tailings impoundments, construction of surface water erosion protection features, and demolition of the mill buildings.

Rio Algom proposes to remove the lined evaporation ponds in Section 4 (Ponds 11 through 21) and Pond 9, and place all the contaminated sediments, dikes, and underlying materials on the existing Tailings Cell 2. The Section 4 ponds are located approximately 2 miles east of the tailings cells, and Pond 9 is located immediately east of Tailings Cell 1. The expanded Cell 2 then will be closed as part of the site Reclamation Plan. Rio Algom estimates that up to 3 million cubic yards of materials will be excavated, hauled, and compacted on the existing Cell 2. The relocation of these materials and placement on Cell 2 would result in raising its surface height approximately 40 feet. The expanded cell will be constructed adjacent to and buttressed on the east side by the west embankment of Tailings Cell 1. The expanded cell would be crowned in the center with a top slope of one to two percent. The outer portions of the cell would be placed on slopes of 5 (horizontal) to 1 (vertical). The cover over the cell would consist of a radon/infiltration layer with a frost protection cover. The radon/infiltration barrier would be designed to keep infiltration extremely low, and limit radon flux to less than 20 picoCuries per square meter per second ($pCi/m^2/sec$) over the long term. The cell cover would be protected against severe precipitation events by a rock protection layer that would be provided to resist erosive processes. A construction management program that incorporates third party Quality Assurance functions would verify that the completed Tailings Cell 2 meets the design intent and is constructed according to project specifications.

Reclamation of the expanded Tailings Cell 2 is intended to 1) control radiological hazards for 1,000 years to the extent reasonably achievable; 2) limit the release of radon-222 from uranium by-product, and radon-220 from thorium by-product materials to the atmosphere so as not to exceed an average of 20 $pCi/m^2/sec$; 3) reduce direct gamma exposure from the reclaimed tailings cell to background levels; 4) avoid proliferation of small waste disposal sites; and 5) provide a final site that is geotechnically stable and provides protection of water resources for the long term. In undertaking this project, the licensee committed to complying with all applicable Federal and State regulations.

The licensee has indicated that this cell expansion design is one component of the overall site Reclamation Plan. The licensee previously has addressed, and NRC has approved, the remaining site-wide Reclamation Plan elements through separate licensing actions, including closure of Tailings Cells 1 and 2, mill demolition, relocation of lined evaporation pond sediments, soil decommissioning plan, and groundwater remediation.

2.0 GEOTECHNICAL ENGINEERING

2.1 Introduction

The NRC staff has reviewed the geotechnical engineering aspects of the Rio Algom Mining, Ambrosia Lake Site, Reclamation Plan for Disposal of Pond Sediments and Ancillary Materials - Tailings Cell 2 Expansion, Revision 1, May 2007. This action by Rio Algom includes the removal of the sediments and the associated impacted materials from the lined evaporation ponds in Section 4 and from Pond 9, and placement of these materials in an expanded northern portion of Tailings Cell 2. The cover over the expanded area would consist of a radon/infiltration barrier, overlain by a frost protection layer and rock erosion protection layers.

This review included an assessment of: (1) information related to the waste disposal site; (2) the characterization of materials associated with reclamation activities, including the cell foundation and excavation materials, the pond sediments and ancillary materials, and other radioactive materials; (3) the design and construction details; and (4) the long-term stability of the waste disposal cell and its cover.

2.2 Site and Material Characterization

The subsurface investigations in the area of the planned disposal cell addition include a previous study in 1982 consisting of 5 borings, and the recent investigation in 2004 consisting of 22 cone penetration tests and 15 pore pressure dissipation tests on the in-situ tailings in Cell 2. These explorations were performed in order to characterize the lithology and material properties of the expansion area in-situ tailings and foundation materials. The logs of the drill holes and cone penetrometer tests were documented in Appendices A-1 and A-2 of the design document respectively.

Geotechnical engineering properties and strength parameters for the tailings materials and natural soils have been determined through laboratory testing, analyses of samples obtained from site investigations, and the cone penetrometer results. These properties include material gradation characteristics, liquid limit, plastic limit, plasticity index, hydraulic conductivity, relative density, shear strength and coefficient of consolidation. A laboratory testing program was conducted to determine the properties of the Section 4 sediments, dike soils, and combinations of the two mixed materials, and included index, shear strength, and compaction (moisture/density) tests.

Rio Algom has acceptably described the geotechnical engineering characteristics of the site, the in-place tailings materials, the evaporation pond contaminated soils, and the natural soils. Geotechnical engineering characteristics were determined using acceptable sampling techniques. Investigations and analyses were conducted with acceptable standards and engineering practices. Laboratory procedures and testing techniques were adequately described and appropriate standards were referenced. The geotechnical engineering characterization of the site and waste materials is sufficient to support engineering assessments related to waste isolation characteristics, permeability characteristics, and long-term stability of the expansion cell for controlling radiological hazards. On the basis of the information presented in the application and the review conducted of the site characterization, the NRC staff concludes that the characterization information, along with other information such as the results of design analyses, provides an acceptable basis to enable the staff to make a finding on compliance with applicable criteria in Appendix A to 10 CFR Part 40.

2.3 Slope Stability

Given that an evaluation of the existing Tailings Cell 2 perimeter slopes was previously performed and accepted, the focus of this expansion slope stability analysis was on the south slope of the proposed cell. At that location, the height of the cell will be greatest, the depth to bedrock will be deepest, and it will include the thickest section of low strength slimes. Four scenarios were analyzed with varying cover thicknesses and silty sand/slime thickness configurations. Soil parameters selected for the analysis were based on data obtained from the 1982 and 2004 investigations and associated laboratory testing. Five different materials were used in the model, pond sediment/ berm mixture, existing soil cover, tailings sands, tailings slimes, and natural soils. Two analytical methods were chosen for evaluation of the stability of the southern perimeter slope: 1) Bishop's Ordinary method using a circular failure surface; and 2) Janbu's method using a block failure along a low-strength layer. The failure surfaces were analyzed under static and pseudo-static conditions using the STABL computer program.

The licensee has acceptably presented the slope stability evaluation by: (1) providing appropriate cross sections and profiles to represent significant slope and foundation conditions; (2) ensuring that slope steepness is five horizontal (5h) to one vertical (1v) or less; (3) providing measurement and selection of static and dynamic properties of soil and rock using acceptable tests and standards; and (4) selecting a location for slope stability analyses that considers the maximum slope angle and slope height, and the weakest materials and foundation conditions. The static load analysis is acceptable and includes: (1) conservative selection of material parameters; (2) consideration of appropriate failure modes; and (3) discussion of the effect of the assumptions inherent in the method of analysis used. The dynamic analysis is acceptable and includes: (1) selection of an appropriate design-level seismic event; (2) evaluations of the dynamic properties and shear strength of the tailings, underlying foundation, and cover materials; (3) computer modeling with appropriate assumptions and methods; and (4) appropriate use of the pseudostatic approach.

Regarding the geotechnical engineering evaluation of slope stability of the tailings expansion cell design, the NRC staff concludes that the slopes of the impoundment are designed to endure the effects of the natural geotechnical forces to which they may be subjected. The stability of the cell with respect to slope failure meets the generally acceptable design requirements, i.e., greater than 1.5 factor of safety for long-term static stability (lowest case, FS=2.4), and greater than 1.0 factor of safety for long-term seismic stability (lowest case FS=1.22).

Based on the information presented in the application and the review of the slope stability for the cell expansion, the NRC staff concludes that the results of the slope stability analysis and the associated models used provide an acceptable basis to demonstrate compliance with the applicable long-term stability criteria in 10 CFR Part 40, Appendix A. The slopes are in compliance with the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c), which requires that impoundment designs provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

2.4 Settlement

The Section 4 and Pond 9 materials will be placed and compacted in a new cell constructed on the existing Tailings Cell 2. The increase in effective stress will produce settlements within the foundation soils and underlying reclaimed tailings.

The licensee has acceptably described settlement due to construction of the expansion cell. Material properties, thickness, and load increments used to calculate settlement are representative of site conditions. Methods used to determine settlement are appropriate for the tailings embankment and soil conditions at the site. The results of the settlement analyses are properly documented. Based on the results, the majority of settlement will take place during construction prior to placement of the cover. Rio Algom is using vertical drains to shorten the time of primary settlement in the northeast area of the existing tailings, and has installed settlement plates to monitor when 90% of settlement is complete. The settlement data provide information to assess the possibility of surface ponding or sudden change of gradient caused by settlement. Data gathered to date have been provided, and indicate that the underlying tailings likely will undergo settlements less than predicted (Rio Algom, 2007b). An acceptable analysis for the development of cracks in the radon/infiltration barrier has been provided.

On the basis of information presented in the application and the review of the characteristics of the settlement resulting from the expansion cell construction, the NRC staff concludes that the settlement and associated conceptual and numerical models present information needed to demonstrate compliance with the criteria in 10 CFR Part 40, Appendix A applicable to stability and cover integrity.

2.5 Liquefaction Potential

The NRC staff has evaluated Rio Algom's analysis of the potential for liquefaction of the tailings and other waste materials in the expansion disposal cell. In this regard, the relocated Section 4 and Pond 9 materials will not be saturated and will be placed as a structural fill. Therefore, liquefaction of the cell itself is not possible. However, it could be possible that saturated lenses and layers within the existing Tailings Cell 2 tailings on which the expansion cell is constructed may be subject to liquefaction under strong ground motion conditions. Rio Algom performed analyses of this liquefaction potential using the simplified Seed and Idriss methodology and using the results of shear wave velocity tests.

For an earthquake magnitude 6.2 (U.S. DOE, 1987), the analyses of saturated layers in the existing tailings result in liquefaction Factors of Safety of 1.2 and 1.9 for the Seed and Idriss and shear wave velocity test methods respectively. Based on this, Rio Algom concludes that liquefaction is not a concern.

The licensee has acceptably evaluated liquefaction potential based on results from properly conducted laboratory and/or field tests. The methods used for interpretation of test data are consistent with current practice. On the basis of the information presented in the application and the review conducted of the liquefaction potential at the tailings site, the NRC staff concludes that the results of evaluation of liquefaction potential present information needed to demonstrate compliance with the criteria in 10 CFR Part 40, Appendix A applicable to stability and cover integrity.

2.6 Design of the Cover

The NRC staff has completed its review of the Cell 2 expansion cover design. The Cell 2 expansion cover design will include 18 inches of compacted Mancos shale radon/infiltration barrier, overlain by 12 inches of Mancos shale frost protection, overlain by a 3-inch rock cover on the top slope, or a 6-inch filter layer and 6-inch rock cover on the side slopes. This design will provide from 2.75 to 3.5 feet of protective cover over the wastes. The impoundment embankment will have side slopes of 20 percent or less and a minimum top slope of 1 percent. The tailings impoundment cover is designed to control the release of radon from the evaporation pond waste, limit infiltration of precipitation, shed precipitation from the cover surface, and protect the impoundment from erosion and from freeze-thaw effects.

Information provided by Rio Algom indicates that the frost penetration depth at the Rio Algom disposal site is 12-inches. In order to ensure that the radon barrier is protected from potential damage of freezing and thawing, a 12-inch layer of processed and compacted Mancos shale will be placed over the Mancos shale radon barrier. The frost depth calculations (modified Berggren method) acceptably demonstrate that the material characteristics and thickness of the additional 12 inches of Mancos shale will provide adequate protection for the radon barrier from freeze-thaw effects (Rio Algom 2007b).

The licensee has acceptably defined the disposal cell cover design by presenting detailed descriptions of the disposal cell material types and/or soil mixtures, including the basis for their selection. With regard to the impoundment cover design, the staff concludes that adequate sources of borrow materials with desired material characteristics (same source as for other covers placed) have been identified for construction of the radon barrier and frost protection. An acceptable schematic diagram displaying various disposal cell layers and thicknesses is provided. A description of the applicable field and laboratory investigations and testing is provided, including identification of material properties. The properties of the cover materials have been addressed properly using appropriate methods.

The NRC staff concludes that the type and thickness of the cover materials will limit infiltration, control the release of radon, and protect the impoundment from potential damage from freeze-thaw cycles. The staff conclusions regarding the adequacy of the cover design to protect the impoundment from adverse effects of erosion are presented in Section 3.0 of this TER. Additional conclusions regarding the radon emanation design are presented in Section 4.0 of this TER. The staff concludes that the cover design will ensure compliance with 10 CFR Part 40, Appendix A, Criterion 4(c), which specifies requirements for the long-term stability of the impoundment cover; and Criterion 6(1), which requires that impoundment designs provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

2.7 Construction Considerations

The NRC staff has completed its review of the construction considerations for the Cell 2 expansion. Rio Algom will institute a third party Quality Assurance program for the duration of the project. This function is intended to ensure that all construction is in accordance with project specifications, that proper testing and inspection are performed to assure project compliance, and that the construction process is properly documented. In addition, quality assurance audits will be performed by an independent consultant. There will be one audit in the first quarter of construction, and a minimum of one audit every four months thereafter. The audits will review construction progress and review all inspection records and testing reports.

Rio Algom will employ appropriate construction methods for the various components of the expansion cell cover design. The clay material for the radon/infiltration barrier will be conditioned, placed on the cell, and compacted (95% standard proctor) in 8-inch loose lifts to obtain the design barrier thickness of 18 inches. The frost protection material also will be conditioned, as appropriate, placed on the cell, and compacted (90% standard proctor) in specified lifts to achieve the design thickness. Waste materials will be conditioned, as necessary, and placed in the cell with construction methods similar to those utilized for the cover materials. The placed materials must meet specifications for moisture, gradation, and density.

Rio Algom will implement an inspection and testing program to ensure quality control of the construction of the various components of the cell. This program will include daily visual inspections of the construction activities related to the placement of the waste and impoundment cover materials. In addition, several types of tests will be performed during construction operations to ensure that construction meets design specifications. These tests include: (1) standard laboratory Proctor tests, (2) gradation analyses, (3) in-place density and moisture content determinations, and (4) measurement of settlement plates. The appropriate standards of the American Society for Testing and Materials (ASTM) will be used for these tests. A daily log will be maintained to document all reclamation construction activities.

The licensee has acceptably described the construction considerations by: (1) providing complete engineering drawings showing all design features; (2) describing sources and quantities of borrow material; (3) including acceptable field and laboratory testing; and (4) identifying methods, procedures, and requirements for excavating, hauling, stockpiling, and placing materials which are consistent with accepted engineering practices for earthen works. Disposal cell compaction plans are supported by field and laboratory tests that assure stability and performance. The licensee has demonstrated that all contaminated materials fit within the planned configuration options of the stabilized pile. An acceptable construction sequence, including a reasonable time to completion, has been described.

The NRC staff finds the inspection and testing program planned by Rio Algom for ensuring quality control in the construction of the cell to be acceptable. Appropriate quality control provisions are in place to ensure that construction will be in accordance with the reclamation plan and that appropriate records will be maintained. With regard to impoundment construction considerations, Rio Algom's methods, procedures, and requirements for excavating, hauling, stockpiling, placing, and compacting contaminated and non-contaminated materials are consistent with commonly accepted engineering practice for earthen works. Appropriate records will be maintained for all construction activities. The staff concludes that these construction considerations will ensure compliance with 10 CFR Part 40, Appendix A, Criterion 4(c), which provides criteria for long-term stability for the slopes of the tailings impoundment and its cover; and Criterion 6(1), which requires that impoundment designs provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

2.8 Disposal Cell Hydraulic Conductivity

The NRC staff has completed its review of the Cell 2 expansion hydraulic conductivity. The licensee has performed permeability tests on the Mancos shale that will be used for the radon/infiltration barrier, and has determined that the permeability ranges from 0.18×10^{-7} to 6.1×10^{-7} cm/sec.

The licensee has acceptably evaluated the disposal cell cover materials hydraulic conductivity by providing sufficient technical basis for the design K-value for the disposal cell. The results of permeability tests indicate that the constructability of the disposal cell with a hydraulic design conductivity of $K<10^{-7}$ cm/sec is likely. A comparison of the hydraulic conductivities of the planned cover and the old existing cover that will now be at the base of the expansion cell indicates that it is unlikely that any "bathtubbing" will occur within the cell.

On the basis of information presented in the application and the review conducted of the disposal cell hydraulic conductivity, the NRC staff concludes that the determination and design of hydraulic conductivity aspects of the cell includes the information necessary to demonstrate compliance with the criteria in 10 CFR Part 40, Appendix A applicable to stability and cover integrity.

2.9 General Geotechnical Conclusions

The licensee has adequately addressed all of the key geotechnical areas required for demonstrating an acceptable plan for reclamation of evaporation pond wastes through construction of an expansion of Cell 2. From a geotechnical engineering standpoint, Rio Algom has provided an acceptable design, and has demonstrated its compliance with applicable criteria in 10 CFR Part 40, Appendix A.

3.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

3.1 Introduction

This section of the TER describes the NRC staff review of surface water hydrology and erosion protection issues related to long-term stability. In this section, the staff provides the technical bases for the acceptability of the licensee's erosion protection design. Review areas that are covered include: estimates of flood magnitudes; water surface elevations and velocities; sizing of riprap to be used for erosion protection; long-term durability of the erosion protection; and testing and inspection procedures to be implemented during construction.

3.2 Hydrologic Description and Site Conceptual Design

To comply with Criterion 6 of 10 CFR Part 40, Appendix A, which requires stability of the tailings for 1000 years to the extent reasonably achievable and, in any case, for 200 years, the licensee proposes to expand the existing Tailings Cell 2 to reclaim the evaporation pond contaminated material and to protect the material 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) events, both of which are considered to have very low probabilities of occurring during the 1000-year stabilization period.

The top surface of the cell will be configured to drain in various directions at a slope of about 1-2 percent, and the embankment side slopes will be constructed to a 1 vertical (V) on 5 horizontal (H) slope. To protect against erosion, the top and side slopes will be covered with layers of rock riprap. At the toes of the side slopes, rock riprap aprons will be constructed to provide protection against the potential migration of gullies toward the disposal cell. Several drainage channels will be constructed at the ends of the aprons to convey flood flows off the disposal cell and away from the disposal area.

3.3 Flooding Determinations

The computation of peak flood discharges for various site design features was performed by the licensee 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 and intensities, corresponding to the computed times of concentration; and (5) calculation of flood discharge. Input parameters were derived from each of these steps and were used to calculate the peak flood discharges to be used in the final determination of rock sizes for erosion protection (Section 3.5).

3.3.1 Selection of Design Rainfall Event

One of the phenomena most likely to affect long-term stability is surface water erosion. To mitigate the potential effects of surface water erosion, the NRC staff considers it very important to select an appropriately conservative rainfall event on which to base the flood protection designs. Further, the staff considers 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 an extrapolation. The licensee utilized a PMP computed by deterministic methods (rather than statistical methods) and based on site-specific hydro-meteorological 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, the staff has concluded that the probability of such an event being equaled or exceeded during the 1000-year stability period is very low. Accordingly, 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 United States by Federal agencies in the form of hydro-meteorological 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.

PMP values were estimated by the licensee using Hydro-meteorological Report No. 55A (HMR-55A) (Hanson, et al, 1988). A 1-hour PMP of 9.6 inches was used by the licensee as a basis for estimating a PMF for the small areas at the site such as the top and side slopes. These procedures for estimating PMP values were reviewed, and it was concluded that the PMP amounts are acceptable for the small drainage areas at the site.

3.3.2 Infiltration Losses

The determination of the peak runoff rate is also dependent on the amount of precipitation that infiltrates into the ground during its occurrence. 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 U.S. Bureau of Reclamation (USBR) 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 (COE, 1988) 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 small drainage areas at the site, the licensee used the Rational Formula (USBR, 1977). In this formula, the runoff coefficient was assumed to be 1.0; that is, the licensee assumed that no infiltration would occur. Based on the conservatism associated with the use of a one-hour PMP of 9.6 inches and a resulting rainfall intensity of approximately 40 inches per hour (See Section 3.3.4, below), the NRC staff concludes that this is an acceptable assumption.

3.3.3 Times of Concentration

The time of concentration (t_c) 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 assumed to be smaller, the peak discharge will be larger. Times of concentration and/or lag times are typically computed using empirical relationships such as those developed by Federal agencies. Velocity-based approaches also are 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.

Times of concentration for the riprap design were estimated by the licensee using the Kirpich Method (USBR, 1977). This method is generally accepted in engineering practice and is considered by the staff to be appropriate for estimating times of concentration at this site. Based a review of the calculations provided, the staff concludes that the t_c values used by the licensee were acceptably derived.

3.3.4 Rainfall Distributions and Intensities

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 one hour. If the time of concentration is less than one hour, it is necessary to extrapolate the data presented in the various hydro-meteorological reports to shorter time periods.

To determine peak flood flows for the cell, the licensee developed a rainfall depth-duration curve using guidelines in HMR-55 and calculated the rainfall intensities for the small drainage areas at the site to be about 40 inches per hour. Based on a review of this aspect of the flooding determination, the staff concludes that the computed peak rainfall intensities are acceptable.

3.3.5 Computation of PMF Discharges

To estimate PMF peak discharges for the top and side slopes, the licensee used the Rational Method (Chow, 1959). This method is a simple procedure for estimating flood discharges that is recommended in NUREG-1623 (Johnson, 2002). In using the Rational Method, the licensee assumed a runoff coefficient equal to 1.0. For a maximum top slope length of about 500 feet (with a slope of 0.01) and a side slope length of about 140 feet (with a slope of 0.2), the licensee estimated the peak flow rates to be about 0.75 cubic feet per second per foot of width (cfs/ft) for the top slope and 0.9 cfs/ft for the side slope.

PMF flow rates for the downstream aprons were estimated by the licensee and are similar to the flow rates for the side slopes. PMF flow rates for the channels were also calculated by the licensee and represent an accumulation of flows down the side slopes.

Based on a review of the calculations, including the time of concentration, rainfall intensity, and runoff, the staff concludes that the licensee's estimated flow rates are acceptable.

3.4 Erosion Protection

The ability of a riprap layer to resist the velocities and shear forces associated with surface flows over the layer is related to the size and weight of the stones which make up the layer. Typically, riprap layers consist of a mass of well-graded rocks which vary in size. Because of the variation in rock sizes, design criteria are generally expressed in terms of the median stone size, D_{50}, where the numerical subscript denotes the percentage of the graded material that contains stones of less weight. For example, a rock layer with a minimum D_{50} of 4 inches could contain rocks ranging in size from 0.75 inches to 6 inches. However, at least 50% of the weight of the layer will be provided by rocks that are 4 inches or larger.

Depending on the rock source, variations occur in the sizes of rock available for production and placement on the reclaimed pile, and it is therefore necessary to ensure that these variations in rock sizes are not extreme. Design criteria for developing acceptable gradations are provided by various sources (e.g., Simons and Li, 1982), and examples of acceptable gradations may be found in NUREG-1623.

3.4.1 Sizing of Erosion Protection

Riprap layers of various sizes and thicknesses are proposed for use at this site, and the design of each layer is dependent on its location and purpose. For ease of construction and to minimize the number of gradations, the licensee has purposely over-designed several areas by providing larger rock than needed in many areas of the slopes and channels.

The top portion of the reclaimed pile will be protected by a 3-inch thick rock layer with a D_{50} of about 1.0 inch. For the side slopes of the cell, the licensee proposes to use 6-inch layer of rock with a minimum D_{50} of 3.2 inches. Methods suggested in NUREG-1623 were used to determine the required rock sizes.

The riprap design for the apron is dependent on the specific location of the apron, and erosion protection needs to be provided against overland flows down the side slope onto the apron. In addition, a specific volume of rock is needed in the apron to protect against gully intrusion into the cell. The design criteria suggested in NUREG-1623 were used to determine rock sizes and rock volumes for the apron.

On the west side of the cell, the rock apron will transition into an area which will receive surface runoff from the cell. These flows will collect in drainage channels along the aprons. The licensee proposes to provide riprap with a D_{50} of 7.8 - 9.2 inches in the channels. Riprap sizes were computed and checked using various methods, including several that are recommended in NUREG-1623.

Based on review of the licensee's analyses and the acceptability of using design methods recommended by the NRC staff, the staff concludes that the proposed rock sizes for the top slopes, side slopes, aprons, and channels are adequate.

3.4.2 Riprap Gradations

Riprap gradations for each of the different rock layers were selected by the licensee using the general guidance provided in NUREG-1623. Based on review of the gradations provided, the staff concludes that the gradations are acceptable.

3.4.3 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 1000 years. In this section, rock durability is evaluated to determine if there is reasonable assurance that the rock itself will survive and remain effective for 1000 years (as required by Criterion 6 of 10 CFR Part 40, Appendix A). To assure that the rock used for erosion protection remains effective for that period of time, potential rock sources must be tested and evaluated to identify acceptable sources of riprap.

The rock source that the licensee has selected for erosion protection of Cell 2 is a dolomitic limestone from the San Andres Formation of Permian age. The limestone is exposed in the Tinaja Quarry located approximately 35 miles southeast of Grants/Milan, New Mexico on State Highway 53. Rock for erosion protection will be produced from a 70-foot-thick, massive, gray to pinkish, limestone unit. Both the licensee and NRC staff observed that the limestone from this unit contains limited and easily identifiable and avoidable features that could be adverse to rock durability. Furthermore, rock units overlying and underlying the selected limestone unit that would not be acceptable for erosion control are easily identifiable and will be avoided during rock production following the NRC approved procedures described in Section 3.4.4.1.

The licensee conducted rock durability tests and petrographic analyses of the limestone unit consistent with the guidance in NUREG-1624. Test results and rock durability scores were provided. Test data from 2001 resulted in a score of 76.7. Based on this score, the licensee incorporated a four percent over design factor for rock diameter sizing to meet the NRC rock quality score of 80. Additional durability tests conducted in 2003 resulted in a score of 83.1. Based on these test scores and observations at the quarry, the staff concludes that the limestone unit to be used for erosion production from the Tinaja Quarry is acceptable when produced using the approved procedures noted in Section 3.4.4.1 and 3.4.4.2.

3.4.4 Testing and Inspection of Erosion Protection

The licensee provided information regarding testing, inspection, and quality control procedures to be used for the erosion protection materials. The information included detailed programs for rock selection during production, durability testing, gradation testing, rock placement, and verification of rock layer thicknesses. Guidance provided in NUREG-1623 was used to develop the programs.

3.4.4.1 Rock Production

The licensee provided rock production procedures to assure that only rock of acceptable quality will be used. The reddish-brown sandstone/siltstone underlying the limestone unit is in the floor of the quarry and therefore not in the production area. The argillaceous limestone with shale interbeds that overlies the limestone unit will be removed and segregated from the limestone unit prior to drilling and blasting. After drilling and blasting, trained personnel at the quarry will monitor and segregate rock that is not high-quality limestone. Rock from the overburden layer, the floor of the quarry, and limestone with undesirable features will be avoided. Undesirable features have been identified and include vugs (voids) and stylolites. Rock blasting and the quarry's crushing processes should result in rock with limited fractures and joints, because the rock will break along these plains of weakness. Based on evaluation of the licensee's procedures, the staff concludes that the rock production process is acceptable.

3.4.4.2 Durability Testing

The licensee's rock durability testing program during production will include the following tests, shown with their American Society of Testing and Materials (ASTM) designation:

1. Bulk Specific Gravity - ASTM C 127
2. Absorption - ASTM C 127
3. Sodium Sulfate Soundness - ASTM C 88
4. L.A. Abrasion at 100 cycles - ASTM C 131 or ASTM C 535
5. Schmidt Rebound Hardness - ISRM Method

Testing and scoring will be performed at a frequency of every 10,000 cubic yards of material produced. Based on a review of the proposed procedures, the staff concludes that an acceptable durability testing program has been provided to ensure that rock of acceptable quality will be provided. The testing program was developed using suggested staff guidance in NUREG-1623 and is equivalent to several which were approved by the staff and have been implemented at other reclaimed sites during construction.

3.4.4.3 Gradation Testing

The licensee proposes that rock gradation testing will be performed at a frequency of one test for every 10,000 cubic yards of material placed. This testing frequency is recommended in NUREG-1623, and is equivalent to the frequency approved by the staff and implemented at other reclaimed sites during construction. In addition, based on evaluations of the actual rock placement and gradations during two site visits, the staff concludes that the gradation testing program is acceptable.

3.4.4.4 Riprap Placement

The licensee provided information regarding the placement of the rock where: (1) riprap will be placed to the depths and grades shown on the drawings; (2) riprap will be placed in a manner to ensure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the void spaces between the larger rock fragments, so that a densely packed, uniform layer of riprap of the specified thickness will result; (3) hand placing will be used, as necessary, to ensure proper results; and (4) material that does not meet these specifications will be either reworked or removed and replaced as necessary.

Based on a review of the licensee's proposal, the staff concludes that the proposed procedures are sufficient to ensure acceptable placement of the riprap. The testing program was developed using guidance found in NUREG-1623 and is equivalent to several which were approved by the staff and have been implemented at other reclaimed sites during construction.

3.5 Surface Water Hydrology and Erosion Protection Conclusions

Based on review of the information submitted by the licensee and on independent calculations, the NRC staff concludes that the erosion protection design is adequate to provide reasonable assurance of protection for 1000 years, as required in Criterion 6 of 10 CFR Part 40, Appendix A.

4.0 RADIATION PROTECTION AND RADON COVER DESIGN

Section 12 of the Rio Algom submitted plan describes the occupational health and safety program that governs radiological activities performed at the site. Rio Algom has stated that it will continue to use its approved ALARA program for this activity and all radiological activities at the site. NRC staff reviewed the elements of the existing program and concludes that, if adhered to, Rio Algom's ALARA program is adequate to protect the health and safety of the workers and the public and protect the environment.

4.1 Radon Attenuation

The limit for the average long-term release of radon-222 (Rn-222) from uranium byproduct materials to the atmosphere is 20 picocuries per square meter per second ($pCi/m^2/s$) from the surface of the tailings cell for 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, as stated in Criterion 6(1) of 10 CFR Part 40, Appendix A. Rn-222, the decay product of Ra-226, is a gas, has a short half-life, and decays to a solid particle. The long-term Rn-222 flux rate can be estimated from the physical and radiological characteristics of the contaminated and radon barrier materials using a series of calculations or a computer code.

4.2 Radon Flux Model Parameters

The licensee used the RADON computer code to estimate the radon flux from the cell. The NRC staff evaluated the input into the RADON computer code to ensure that the values are either based on site-specific testing or are conservative estimates. The staff also evaluated the justification and assumptions made in choosing these values and confirmed that each input value was representative of the proposed material, consistent with anticipated construction specifications, and based on long-term conditions.

The licensee's flux model used a contaminated material thickness of 500 centimeters (cm), which is conservative. Data from evaporation pond samples indicate that the current Ra-226 activity level is an average of 31.3 pCi/g. Additionally, the licensee estimated that Thorium in-growth would contribute 287.2 pCi/g at 1000 years. The current Ra-226 levels would decay to 20.3 pCi/g at 1000 years, thus yielding a total activity of 307.5 pCi/g at 1000 years. However, the licensee states that it intends to have a 50/50 mix of sediments and soils thus lowering the 1000 year Ra-226 level to 154 pCi/g, which is the value that is used in the RADON code. The licensee also used a program default emanation coefficient of .35, and a code-calculated diffusion coefficient, both of which are conservative estimates. The long-term moisture content of 15% for the sediments was calculated using the methodology in Regulatory Guide 3.64 (NRC, 1989) and is a conservative estimate.

4.3 Modeling Results

Rio Algom used the RADON computer code to calculate the long-term radon flux (NRC, 1989). The Rio Algom flux model results indicate that the proposed cover will limit the expected radon flux from the 12.9 pCi/m^2/s. The NRC staff also independently modeled the Rio Algom cover design using the RADON computer code and the selected parameters. The NRC model calculated an exit flux of 13.31 pCi/m^2/s with radon retention of approximately 92%

4.4 Radon Barrier Design Conclusions

The NRC staff determined that the radon flux was calculated appropriately using conservative estimates and site specific data where appropriate. NRC staff has determined the cover is adequate to meet the requirements set forth in Criterion 6(1) of 10 CFR Part 40, Appendix A.

5.0 SUMMARY

Based on its technical review of the plan submitted by Rio Algom, the NRC staff concludes that the expanded Tailings Cell 2 reclamation of evaporation pond contaminated materials will: 1) control radiological hazards for 1,000 years to the extent reasonably achievable; 2) limit the release of radon to the atmosphere to less than 20 pCi/m^2/sec; 3) reduce direct gamma exposure from the reclaimed tailings cell to background levels; 4) avoid proliferation of small waste disposal sites; and 5) provide a final site that is stable and provides protection of water resources for the long term. The plan will ensure that the evaporation pond materials are disposed of in the reclaimed tailings cell in a manner that is protective of human health and the environment and in accordance with The Uranium Mill Tailings Radiation Control Act, as amended, and regulations in 10 CFR Part 40.

Acceptance and approval of the Rio Algom Reclamation Plan for expansion of Cell 2 will be documented in an amendment of License No. SUA-1473. The NRC staff proposes the following addition to Condition No. 37 of the license:

“In addition, final disposal of evaporation pond sediments located at Section 4 and Pond 9 shall be performed in accordance with the Tailings Cell 2 Expansion Reclamation Plan, Revision 1, submitted by letter dated May 31, 2007 and supplemented by letter submittals dated August 1, 2007, and September 18, 2007.”

6.0 REFERENCES

ASTM, 1995; American Society for Testing and Materials, "1995 Annual Book of ASTM Standards," Philadelphia, PA, 1995.

Chow, 1959; *Open Channel Hydraulics*, Chow, V.T., McGraw-Hill Book Co., New York, 1959.

COE, 1988; “U.S. Army Corps of Engineers HEC-1 Flood Hydrograph Package,” Hydrologic Engineering Center, Davis, CA, 1988

DOE, 1987; Remedial Action at the Ambrosia Lake Uranium Mill Tailings Site, Ambrosia Lake, New Mexico; U.S. Department of Energy, DOE/EA-0322, June 1987.

Hansen, et al, 1988; “Probable Maximum Precipitation Estimates - United States Between the Continental Divide and The 103rd Meridian,” Hydro-meteorological Report No. 55A, 1988.

Johnson, 2002; “Design of Erosion Protection Covers for Long-Term Stabilization,” NUREG-1623, Johnson, Terry L., U. S. Nuclear Regulatory Commission, 2002.

NRC, 2003; NUREG-1620, Rev. 1, “Standard Review Plan for Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978,” Nuclear Regulatory Commission, Washington, DC, 2003.
[ADAMS Accession No. ML040560561]

NRC, 1989; Regulatory Guide 3.64, Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers [ADAMS Accession No. ML003739876]

Rio Algom Mining LLC, 2004, “Closure Plan-Lined Evaporation Ponds,” submitted under cover letter dated November 1, 2004. [ADAMS Accession No. ML050240058]

Rio Algom, 2005; Reclamation Plan for Disposal of Pond Sediments and Ancillary Materials, Tailings Cell 2 Expansion, April 30, 2005. [ADAMS Accession No. ML051290050].

Rio Algom 2007a; Reclamation Plan for Disposal of Pond Sediments and Ancillary Materials, Tailings Cell 2 Expansion, Revision 1, May 2007; transmitted under cover letter dated May 31, 2007. [ADAMS Accession Nos. ML071790245 and ML071790250].

Rio Algom 2007b; Pond 2 Cell Design Plan Revisions, August 1, 2007 [ADAMS Accession Mo. ML072260507].

Simons and Li, 1982; "Surface Mining Diversions Design Manual," Simons, D.B. and R.K. Li, Office of Surface Mining, United States Department of the Interior, OSM/TR-52/2, September 1982.

Stevens, M.A., D.B. Simons, and G.L. Lewis, "Safety Factors for Riprap Protection," American Society of Civil Engineers, Journal of the Hydraulics Division, v. 102, No. HY5, 1976.

USBR, 1977; *Design of Small Dams*, U.S. Bureau of Reclamation, U.S. Department of the Interior, 1977.