TECHNICAL EVALUATION REPORT
RIO ALGOM MINING CORPORATION
DIVERSION OF ARROYO DEL PUERTO
SURFACE WATER HYDROLOGY AND EROSION PROTECTION

1. Introduction

Rio Algom Mining Corporation (RAMC), formerly Quivira Mining Company, is conducting reclamation of its uranium processing facility located in the Ambrosia Lake Valley northeast of Grants, New Mexico. This technical evaluation report (TER) describes the staff's review of surface water hydrology and erosion protection issues related to long-term stability of the proposed diversion channel for the Arroyo Del Puerto (ADP). In this report, 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.

As part of the reclamation program, RAMC has reclaimed Tailings Pond 1 and is in the process of reclaiming Tailings Pond 3. Erosion protection designs for Tailings Ponds 1 and 3 were submitted to the NRC on September 26, 2002. The NRC staff reviewed the designs and transmitted a TER to RAMC on November 27, 2002. In this TER, the NRC staff concluded that the designs appropriately addressed the long-term erosion protection of Tailings Ponds 1 and 3 and issued Amendment 51 to update License Condition No. 37. However, in that TER, the staff concluded that the toe of Tailings Pond 3 should be re-evaluated to determine if the erosion protection adequately protected against lateral migration of the Arroyo del Puerto and the potential for undercutting the toe of Tailings Pond 3. In response to this TER, RAMC submitted a report assessing the potential for lateral migration of the ADP. The staff issued another TER on October 5, 2004, addressing the lateral migration report. This second TER concluded that since the maximum differential distance between the toe of Tailings Pond 3 and the re-established channel bed would only be approximately 10 feet, RAMC should reevaluate the potential for undercutting of the impoundment toe due to the potential migration of the arroyo.

In meetings with the licensee in 2006, the staff learned that RAMC intended to leave the contaminants remaining under Ponds 4, 5, and 6 in place in the ADP floodplain. The staff expressed concerns that these materials needed to be protected from erosion that could occur in the ADP channel and floodplain. RAMC's decision to leave this material in place has resulted in significant changes to the overall design of diversion channel for the ADP. Major revisions include construction of a very large diversion channel and significant additions of riprap to protect against erosion and lateral migration of the re-aligned arroyo.

This TER is based on review of the following licensee submittals: (1) "Site Erosion Protection Measures From Surface Water Flow in The Arroyo Del Puerto," Revision 1 dated January 2008 (See ADAMS ML080350250, ML080350251, ML080350252, ML080350254, and ML080350259); and (2) "Site Erosion Protection Measures From Surface Water Flow in The Arroyo Del Puerto," Amendment 1 to Revision 1, dated March 2008 (See ADAMS ML080990026, ML080990027, ML080990034, and ML080990035).

2. Hydrologic Description and Site Conceptual Design

To comply with Criterion 6(1) of 10 CFR 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 proposed to significantly modify the alignment of the ADP by constructing a new channel and berm on the east side of contaminated materials in Ponds 4, 5, and 6. As shown on Sheet 4 of the licensee's submittal, the overall design includes construction of: (1) a new exterior diversion channel and berm; (2) a new interior drainage channel; (3) modified riprap protection for Pond 3; and (4) additional riprap protection for Ponds 4, 5, and 6. Each of these design features requires rock riprap erosion protection to assure long-term stability.

3. 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, it is very important to select an appropriately conservative rainfall event on which to base the flood protection designs. Further, 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 Probable Maximum Precipitation (PMP) computed by deterministic methods (rather than statistical methods) and 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, 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 a drainage basin, the flooding analysis requires the determination of the PMP for a specific site location. Techniques for determining the PMP have been developed for specific regions of the United States by Federal agencies in the form of hydrometeorological reports. These techniques are widely used and provide straightforward procedures with minimal variability.

PMP values were estimated by the licensee using Hydrometeorological 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 Probable Maximum Flood (PMF) values for the small drainage areas at the site. These procedures for estimating the PMP values were reviewed, and the PMP amounts were found to be acceptable.

4. Infiltration Losses

In addition to the amount of precipitation, the determination of the peak runoff rate is also dependent on the amount of precipitation that infiltrates into the ground and does not contribute to flood flows. If the ground is saturated from previous rains, very little of the rainfall will infiltrate and most 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. In this formula, the runoff coefficient was assumed to be 1.0 (the licensee assumed that no infiltration would occur). Based on the conservatism associated with the assumption of no infiltration, the staff concludes this procedure is acceptable.

5. 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 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.

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 are acceptable.

6. 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 hydrometeorological reports to shorter time periods.

To determine peak flood flows for the smaller drainage areas, 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. Based on a review of this aspect of the flooding determination, the staff concludes that the computed peak rainfall intensities are acceptable.

7. Erosion Protection Design for Ponds 4, 5, and 6

RAMC has proposed leaving existing Ponds 4, 5, and 6 in place. These ponds extend over an area of about 50 acres and contain contaminated material that must be stabilized and protected from erosion. They are located inside the exterior diversion berm, but need to be protected from the effects of direct precipitation and the resulting overland runoff. RAMC would provide a 3-inch thick layer of rock with a D_{50} of 1.0 inches to protect the top slope from erosion. This rock size was computed using methods suggested in NUREG-1623, using a maximum slope length of about 2400 feet, an average top slope of 0.85 percent, and a maximum flow rate of 1.2 cfs/ft. Based on review of the calculations, the staff concludes that the proposed rock size is acceptable.

8. Erosion Protection Design for Interior Drainage Channel

RAMC intends to construct an interior drainage channel to convey flows that are produced inside the exterior diversion berm. These flood flows will be derived from various drainage areas located in the general vicinity of Ponds 1, 3, 4, 5, and 6. The channel will be about 4800 feet long and will have a bottom width of 125–190 feet, with side slopes of 1V on 5H. The channel bottom will have a 1.5% cross-slope to the northeast (away from Pond 3). The channel will begin at the upstream end of Pond 4 and will join the exterior diversion channel near Pond 9. Two channels that have already been constructed (diversion channel and discharge channel - See Sheet 4) will discharge into the interior drainage channel at two separate locations.

The PMF for the interior drainage channel at various locations along the channel were developed using the Rational Formula (USBR, 1977). For the extreme downstream end of the channel (at its confluence with the exterior channel), with a drainage area of 0.69 square miles, RAMC computed the peak PMF flow to be about 9750 cfs.

Water surface profiles, velocities, and energy grade line (EGL) slopes were computed using the HEC-RAS (USACE, 1999) computer program. The velocities and EGL slopes were used to determine riprap sizes using the Abt-Johnson Method discussed in NUREG-1623. Manning's 'n' values were developed using methods developed by the U. S. Army Corps of Engineers and discussed in NUREG-1623.

Scour depths were computed using the U. S. Army Corps of Engineers Equilibrium Scour Depth Equation (USACE, 1999). These scour depths were then used to determine the size and thickness of rock aprons that will be placed at the toes of the side slopes to prevent undermining of the riprap slopes. The scour depths ranged from 1.5 to 3.2 feet, and RAMC proposes to provide aprons that are at least as thick as the scour depths at specific channel locations.

RAMC also evaluated the possibility of lateral (perpendicular to the channel alignment) inflows to the channel to determine if these inflows would produce a more critical design condition for the side slope rock. After these evaluations, it was determined that the rock size was adequate to resist the occurrence of concentrated lateral inflows down the side slopes.

Based on review of the RAMC calculations and design assumptions, including Manning's n values, water surface profiles, and riprap sizes, the staff concludes that the erosion protection design for the interior drainage channel is acceptable.

9. Erosion Protection Design for Tailings Pond 3

A previous RAMC submittal ("Design Report, Pond 3 Erosion Protection and Erosion Protection for the Area North of Pond 1, Ambrosia Lake Mill, New Mexico") evaluated the erosion protection for the side slopes of Tailings Pond 3 for two different precipitation events. The first was the local PMP storm that would fall on the slope of Tailings Pond 1 and discharge onto the surface of Tailings Pond 3, combined with the run-off accumulated from rain that falls onto Tailings Pond 3. The accumulated flows would run off the pond surface and onto the embankment slope and apron. The second event was a PMF that could occur in the ADP drainage basin. The previous evaluation determined that the PMF would produce the larger erosion forces. The report concluded that the over-bank velocities would be 11 fps at a depth of 10 ft, and predicted a D_{50} of 12 inches for erosion protection on the side slope.

However, under the proposed design that diverts the flood flows in the ADP, the PMF in the ADP does not impact upon Tailings Pond 3, since it is protected by the diversion berm. Therefore, the localized storm event was used to determine rock sizes. These revised calculations resulted in a design that uses: (1) a 24-inch thick layer of rock with a D_{50} of 7.8 inches for the toe/apron at the base of Pond 1, where it transitions onto the top slope of Pond 3; (2) a 3-inch thick layer of rock with a D_{50} of 1.0 inches for the top surface of Pond 3; (3) a 9-inch thick layer of riprap with a D_{50} of 3.2 inches for the side slope; and (4) a 36-inch thick layer of rock with a D_{50} of 9.2 inches for the apron at the base of the slope.

Based on review of the information provided and the use of methods suggested in NUREG-1623, the staff concludes that the design of the Pond 3 erosion protection is acceptable.

10. Erosion Protection for Exterior Diversion Channel and Berm

RAMC proposes to construct a diversion channel to convey PMF flows that are produced in the ADP drainage basin. The channel will be about 8600 feet long and will have a bottom width of 250 feet for most of its length. The channel will begin about 2000 feet upstream of Pond 4 and will join the interior diversion channel near Pond 9 (See Sheet 4 of licensee's submittal).

A PMF of 78,000 cfs for the exterior drainage channel, with a drainage area of 57.6 square miles, was determined by RAMC in previous submittals and was approved by the NRC staff (NRC, 2002). For this review, it was decided that the NRC staff would not revisit this estimate, and the estimate was accepted for use in the design of the exterior drainage channel.

Water surface profiles, velocities, and EGL slopes were computed using the HEC-RAS (USACE, 1999) computer program. The velocities and EGL slopes were used to determine riprap sizes using the Abt-Johnson Method discussed in NUREG-1623.

Scour depths were computed using the U. S. Army Corps of Engineers Equilibrium Scour Depth Equation (USACE, 1999). These scour depths were then used to determine the size and thickness of rock aprons that will be placed at the toes of the side slopes to prevent undermining of the riprap slopes. The scour depths range from 3.2 to 12.0 feet, and RAMC proposed to provide aprons that extend to the scour depth at the specific location. In some locations near the downstream ends of the channels, bedrock is present, and RAMC proposed to extend the rock to a depth where it meets the bedrock. The erosion protection will be keyed into the rock in accordance with methods recommended by the U. S. Army Corps of Engineers (USACE, 1991).

The staff determined that additional protection is provided by the 1.5 percent cross-slope of the channel away from the protected areas. Maximum depths, velocities, scour depths, and shear stresses will occur in the deeper parts of the channel, which are located hundreds of feet from the riprap-protected berm. This will minimize the potential for high velocities to occur near the berm.

Based on review of the information provided by RAMC, the staff concludes that the riprap design for the exterior drainage channel is acceptable.

11. Channel Inlets and Outlets

In general, the upstream and downstream ends of diversion channels usually need to be protected from the effects of gullying and flow concentrations. At the upstream channel inlet, it is

necessary to prevent flows in naturally-occurring gullies from impacting the beginning of the erosion protection. At the downstream end of diversion channels, it is usually necessary to prevent head-ward gully migration from impacting the erosion protection. To accommodate this problem, RAMC proposed to provide thickened aprons of larger rock to prevent gully erosion.

Based on review of the proposed designs, the staff concludes that the designs meet the suggested criteria of NUREG-1623 and are acceptable.

12. Riprap Gradations

Riprap gradations for each of the different rock layers were selected by the licensee using the general guidance provided in NUREG-1623. Gradations were provided for each of the various layers, including rock with D_{50} values of 1.0, 3.2, 7.8, and 9.2 inches.

Based on review of the gradations provided, the staff concludes that the gradations are acceptable.

13. Rock Selection, Testing, and Inspection for 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 thickness. Guidance provided in NUREG-1623 was used to develop the programs.

RAMC intends to use limestone rock that will be produced from the Tinaja quarry. This quarry was also used to produce rock for the Cell 2 Expansion (See TER for Tailings Cell 2 Expansion, December 10, 2007, ADAMS ML073050316). It is an acceptable source, since the staff previously has reviewed the rock from this source and approved it for use on the Cell 2 Expansion.

a. Rock Selection During Production

The licensee provided a description of the rock that will be produced at the Tinaja quarry and provided procedures to assure that only rock of acceptable quality will be used. The overburden layer will be removed and segregated from the acceptable rock 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 or the floor of the quarry will not be used.

Based on evaluation of the licensee's procedures, the staff concludes that the selection process is acceptable.

b. Durability Testing

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(1) 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 licensee's proposed rock durability testing program 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

At least one petrographic examination will be performed for each rock type used. Testing will be performed in accordance with ASTM C-295-90.

The testing program was developed using suggested staff guidance in NUREG-1623 and is equivalent to several other testing programs which were approved by the staff and have been implemented at other reclaimed sites during construction.

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 used.

c. Gradation Testing

The licensee proposed 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 other testing frequencies approved by the staff and have been implemented at other reclaimed sites during construction. In addition, the staff evaluated the actual rock placement and gradations during two site visits. The staff concludes that the gradation testing program is acceptable.

d. 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.

The testing program conforms to the general 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.

Based on a review of the licensee's proposal, the staff concludes that the proposed information and procedures are sufficient to ensure acceptable placement of the riprap.

14. Sediment Considerations

In general, in this area of northwestern New Mexico, sediment accumulations can pose a problem in the design of diversion channels. In many instances, diversion channels are constructed to convey flood flows where the slope of the channel is radically lessened. In this

specific case at Rio Algom, the channel slope is not dramatically altered, and the channel configuration could more properly be considered as a channel re-alignment, rather than a channel diversion. In any case, the slope of the re-aligned channel is not significantly different than the original slope of the ADP.

The geomorphic processes upgradient from the site consist of sheet flow and ephemeral channel flow, wind erosion, and eolian deposition. In addition, there is a high infiltration rate associated with the thick surficial alluvial deposits that significantly reduces the potential for gullying and sediment production. The lack of gullying in the lower Ambrosia Lake valley indicates that relatively permeable surface materials have resulted in rapid infiltration rates with very little surface runoff.

The ADP is the only well defined channel in the lower part of the basin. Tributary channels are poorly defined as a result of a lack of flow concentration caused by infiltration and dissipation of runoff. Encroachment of the ADP against the resistant bedrock outcrops is the cause of flow concentration and channel development along the course of the drainage.

RAMC provided analyses to show that most of the fine-grained sediment that is produced in the drainage basin will be conveyed past the site at a relatively high velocity during flood flows. The slope of the channel is such that the higher velocities will flush sediment from the re-aligned ADP channel, and sediment will not be deposited in any significant quantities. In addition, as discussed above, RAMC provided geomorphic information to document the overall stability of the drainage basin in the vicinity of the site.

RAMC also provided HEC-RAS analyses to show that overtopping of the diversion berm would not occur, even if significant sediment accumulation occurred in the exterior diversion channel. The analyses showed that the increase in water levels in the channel would be insignificant, primarily because flood flows would spread further into the left over bank.

15. Conclusions

For an erosion protection design at an existing site, 10 CFR Part 40, Appendix A specifies, in part, that the design must remain effective for a period of 200-1000 years, with no reliance placed on active maintenance to preserve isolation of contaminated material. Based on its review of the information submitted by the licensee and on independent calculations, the NRC staff concludes that the erosion protection design for the ADP meets applicable Appendix A requirements and that adequate protection is provided by the following:

(1) The erosion protection has been designed to protect the site from rainfall and flooding events that have very low probabilities of occurrence over the required 1000-year design period, with no damage to the riprap layers resulting from the occurrence of such events.

(2) Appropriate and /or conservative parameters were used to determine flood discharges, flood levels, flood velocities, scour depths, and riprap sizes.

(3) The rock types that were selected for use as erosion protection will be durable for long periods of time, and the durability of the rock will be verified by standardized and acceptable testing procedures.

(4) The rock layers will be placed in accordance with accepted engineering practice and in accordance with appropriate testing and quality assurance controls.

16. REFERENCES AND BIBLIOGRAPHY

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

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

Hansen, et al. "Probable Maximum Precipitation Estimates - United States Between the Continental Divide and The 103rd Meridian," Hydrometeorological Report No. 55A, 1988.

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

Rio Algom Mining LLC. "Site Erosion Protection Design for Surface Water Flow in the Arroyo Del Puerto," October 2007. (See ADAMS ML073060379, ML073060380, ML073060381, ML073060382, and ML073060383).

Rio Algom Mining LLC. "Revision I of the Site Erosion Protection Design for Surface Water Flow in the Arroyo Del Puerto," January 2008. (See ADAMS ML080350250, ML080350251, ML080350252, ML080350254, and ML080350259).

Rio Algom Mining LLC. "Amendment 1 to Revision I of the Erosion Protection Design for Surface Water Flow in the Arroyo Del Puerto," March 2008. (See ADAMS ML080990026, ML080990027, ML080990034, and ML080990035).

Simons, D.B. and R.K. Li. "Surface Mining Diversions Design Manual," 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.

U. S. Army Corps of Engineers (USACE). "Hydraulic Design of Flood Control Channels," EM 1110-2-1601, July, 1991.

U. S. Army Corps of Engineers (USACE). "HEC-RAS River Analysis System," Version 2.2, Hydrologic Engineering Center, Davis, California, 1998.

U. S. Army Corps of Engineers (USACE). "Equilibrium Scour Depth at Tidal Inlets," Coastal Engineering Technical Notes IV-18, March, 1999.

U.S. Bureau of Reclamation. "Design of Small Dams," U.S. Department of the Interior, 1977.