Geotechnical Engineering Technical Evaluation Memorandum

Shiprock Site Remedial Action Plan

Prepared by: Dr. Banad N. Jagannath, WMEG

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1.0 PROPOSED REMEDIAL ACTION

The tailings at the Shiprock site are located in two adjacent piles covering approximately 72 acres. The piles contain 1.9 million cubic yards of tailings, contaminated rubble, and soil materials. The proposed remedial action calls for (1) relocation of radioactive tailings away from the edge of the escarpment; (2) removal of contaminated materials from the site yard area, adjacent and flood plain areas, and vicinity properties; and (3) consolidation of all contaminated materials in a single large embankment in the same approximate locations as the two existing tailings piles. The gently contoured embankment (side slope of 5 horizontal to 1 vertical) will then be covered with a 7-foot thick earthen layer and a rock layer to ensure: (1) long-term stability while simultaneously reducing radon emissions; (2) reduced infiltration of precipitation (thereby avoiding contaminated recharge to the shallow ground water system); (3) protection of surface water quality; (4) prevention of animal intrusion; (5) minimized plant root intrusion; (6) prevention of inadvertent human intrusion; and (7) prevention of materials dispersion (Reference 1).

Relocating the tailings away from the escarpment will prevent the release of contaminated material resulting from the undercutting and slope degradation of the escarpment. Site regrading combined with stabilization of the escarpment edge will retard long-term escarpment erosion and prevent surface-water runoff and river contamination. Fencing the perimeter of the consolidated pile and posting warning signs will discourage human intrusion. The geotechnical aspects of the proposed remedial action have been reviewed for compliance with the EPA standards with respect to stability and radon control (40 CFR Part 192).

2.0 GEOTECHNICAL SITE CHARACTERIZATION

2.1 Site Description

The Shiprock site is located on the Navajo Indian Reservation on the south side of the town of Shiprock, New Mexico. It lies on an escarpment on the southwest bank of the San Juan River, 70 feet above the river flood plain. Farmington, New Mexico, is approximately 30 miles east of the Shiprock site. The

designated site contains 144 acres, of which about 72 acres are covered with tailings in two adjacent piles. The upper (northern) pile covers 26 acres and varies from 14 to 40 feet in height. The lower (south) pile covers 46 acres and is approximately 15 feet in height. Four of the original mill buildings and two new buildings are on the site. The tailings pile was covered and stabilized, but the present condition of the pile does not meet the EPA standards. Dikes presently around the tailings pile prevent the spread of tailings from the run-off water erosion. The dikes and the site surface grading direct other off-site and on-site surface run-off toward existing arroyos off the edge of the escarpment.

Several of these arroyos close to the tailings pile are actively eroding the escarpment from above. High winds combined with the steep side slopes on the upper tailings pile have exposed the thinly covered tailings to both rainfall and wind erosion.

2.2 Site Investigations

Subsurface investigations were performed at the Shiprock site by five contractors - Colorado State University (1979, 1981), Dames and Moore, (1982), Sergent, Hawkins & Beckwith (1983), Bendix Field Engineering Corporation (1983), International Engineering Company (1984) (References 1, 2, & 3). The scope of the geotechnical investigations included borings from which soil samples and rock cores were obtained, test pits from which bulk soil samples were obtained, and installation of monitoring wells. However, the work by Bendix was primarily for radiological survey of the tailings pile and adjacent areas.

2.3 Stratigraphy

The overburden generally consists of a surface layer of silt and silty sand underlain by sandy gravel with cobbles. These alluvial terrace deposits are about 10 ft. thick at the escarpment and about 40 ft. thick at the southwest corner of the tailings pile. The bedrock at this site is identified as Mancos shale which predominantly consists of claystones and silt stones. Mancos shale is estimated to be several hundred feet thick at this site.

The upper natural soils at the site predominantly consists non-plastic to low plasticity sandy silts, silty sands and sandy clays (ML, SM, CL). These soils generally extend to depths of 5 to 30 ft. below the natural ground surface, thickening to the south-southwest.

These fine grained soils are underlain by a stratum of sandy gravel containing numerous cobbles and small boulders and is interbedded with layers of clean fine sand and sandy silt and clay.

The upper 10 to 30 feet of Mancos shale is typically highly weathered - exhibiting fractures, fissility, and low strength. Below the highly weathered zone, the bedrock is moderately weathered, more competent, and relatively impermeable.

Groundwater exists in the alluvial deposits near or below the tailings/soil interface. This water appears to be perched and laterally discontinuous across the site. A continuous water system exists in the upper weathered portion of the Mancos shale, which underlies the alluvial deposits.

The tailings site is generally rectangular in shape consisting of two piles - an upper pile (closest to the river) and a lower pile. The upper pile is approximately 14 to 40 feet thick and the lower pile is about 15 to 30 feet thick above the natural soils. The side slopes are about 1.6 horizontal to 1.0 vertical. Soil cover placed during a previous minor remedial action is present only at some locations on the tailings pile. The tailings consists of interbedded sands (SP-SM) and slimes (CL-ML). These materials are interbedded in thin lenses that are discontinuous, both vertically and horizontally. The term slime is used to define the fine portion of the tailings with a relatively high moisture content and moderate plasticity. The slimes have layers of silt and clay interbedded during the mill tailings depositional process.

2.4 Testing Program

Details of the borings, test pits, and laboratory tests comprising the geotechnical engineering subsurface exploration and testing program for the Shiprock site (References 1, 2, 3, & 4) were examined by the staff. Based on this review, the staff finds that the exploration programs have adequately covered the site and borrow area and were consistent with standard engineering practice. Because of the interbedded and erratic nature of the tailings pile it was difficult to obtain undisturbed samples of the slimes from borings; however, they were obtained from test pits. The staff finds that the testing program employed to define the material properties was appropriate for the support of the necessary engineering analyses described in the following sections and that the data collected in the exploration program was sufficient to describe the site characteristics.

3.0 GEOTECHNCIAL ENGINEERING ANALYSES

The following geotechnical engineering aspects of the remedial action have been reviewed by the staff:

A. Stabilized Tailings Pile

- o Slope Stability
- o Settlement
- o Liquefaction
- o Cover Design

B. Site Improvements

- o Stability of Arroyo Slopes

3.1 Stabilized Tailings Pile

3.1.1 Slope Stability

The staff has reviewed the exploration data, test results, critical slope characteristics and methods of analyses pertinent to the slope stability aspects of the remedial action plan (Reference 1 & 4). The critical cross section of the slope, 5 horizontal to 1 vertical, used in the analysis has been compared with the exploratory records and design details. The staff finds that the characteristics of the slopes have been accurately represented, and that the most critical slope section (northeast section of the upper tailings pile) has been considered for the analysis. Soil parameters for the slimes, which comprise the critical layer for the slope stability analysis, have been established by testing. Values of soil parameters have been assigned to other non-critical layers (sand, sand-slime, etc.) on the basis of data obtained from geotechnical explorations at this site and data published in the literature. The staff finds that the methods used to estimate the values of these soil parameters were appropriate. The staff also finds that the stability analysis has employed state-of-the-art techniques (sliding wedge method of analysis) and has addressed the likely adverse conditions to which the slope might be subjected. Factors of safety against failure of the slope for both static and seismic loading conditions have been evaluated for short term or end-of-construction state. For the static loading conditions, the minimum factor of safety against failure of the slope was reported as 1.9. The staff finds the factor of safety to be acceptable for static loading conditions. The stability of the slope for the seismic loading condition was investigated by the pseudo-static method of analysis using a horizontal seismic coefficient of 0.13. The staff finds the pseudo-static method of analysis is acceptable

considering the degree of conservatism in the soil parameter values and the flatness of the slope (5H:1V). A minimum factor of safety of 1.1 has been reported for the seismic loading condition. This is higher than an acceptable minimum factor of safety of 1.0 for seismic loading conditions.

The staff has noted that the reported stability evaluation has used short-term or undrained strength parameters for the slime materials. The long-term strength parameters for slimes would be significantly higher than the strength parameters used in the above analysis and the factors of safety of the slope for the long-term conditions would be higher than those calculated for the short-term conditions. Therefore, it is concluded that the slopes would be stable for the long-term conditions.

The staff is aware that the NRC has not yet accepted the maximum credible earthquake at the site estimated by the DOE (peak acceleration of 0.13g) and therefore, the above conclusion is conditional on an NRC finding that the maximum credible earthquake at the site does not produce a maximum ground acceleration in excess of 0.13g at the site. Subject to this condition, the staff concludes that the stabilized tailing pile slopes are expected to be stable under both short-term and long-term conditions.

3.1.2 Settlement

The staff has reviewed the DOE's analysis of total and differential settlements resulting from compression and consolidation caused by the placement of a radon barrier cover over the reworked and compacted tailings in the stabilized pile. The staff considers that the in situ foundation soils (silty sand and sandy gravel) do not contribute to any time dependent settlement. Any compression of these foundation soils as a result of the imposed loading will be elastic settlement which will be accommodated during construction. The reported settlement analysis used consolidation parameters determined by laboratory tests (References 1 & 4). Staff review of the settlement calculations indicate that the material properties and stratigraphy used in the analyses are representative of the site conditions, and appropriate analyses and techniques have been used.

Maximum total settlement at the critical analysis section (thick slime pocket) has been estimated to be 1.0 foot. Settlement at typical (average condition) section is estimated to be 6 inches. Since the tailings will be mixed with sand and compacted, it is expected that most of the settlement will occur during construction. To limit the effect of settlement on cover, the DOE has committed to monitor settlement during construction and to perform final grading of the cover only after most of the settlement has taken place.

Differential settlement can lead to cover cracking and/or concentration of surface runoff. The DOE has concluded that differential settlement expected to occur after cover placement will not be of a magnitude that would cause cover cracking. Although some differential settlement is expected to occur, the staff concludes that it will be minimized by the fact that tailings will be mixed with sand, which will promote drying, and compacted into an engineered fill and final grading will be performed after most of the settlement has taken place. The staff agrees with the DOE's conclusion that the estimated settlement at this site should not present a problem.

3.1.3 Liquefaction

The staff reviewed the results of the geotechnical investigations including boring logs, test data, and soil profiles, and conclude that the DOE has adequately assessed the potential for liquefaction at the Shiprock site. Because the compacted dry density of the stabilized pile will be equal to 90 percent of that determined by ASTM D-698 test and the pile design provide for the pile materials to be in an unsaturated condition, the embankment is not considered to be susceptible to liquefaction. The DOE's liquefaction analysis for pockets of saturated slime within the pile was accomplished using the simplified method of Seed and Idriss and concluded that for a design earthquake acceleration of 0.13g, the slime pockets are not susceptible to liquefaction (Reference 1). However, since there may be pockets of slime located adjacent to embankment slope which will undergo deformation during a seismic event, small local deformation in the vicinity of the toe of the embankment cannot be ruled out.

The subsoils at the site are in a relatively dense condition and are expected to be in an unsaturated condition. Therefore, the foundation soil beneath the tailings embankment is also not considered susceptible to liquefaction.

The staff concludes that an acceptable analysis has been performed which indicates that the stabilized pile is not expected to be susceptible to liquefaction. However, the staff considers that seismically induced ground motions may produce deformation in pockets of slime which might result in slight disruption at the toe of the pile. A license requirement for mandatory inspection following a significant seismic event is recommended. The magnitude of the seismic event which triggers a mandatory inspection should be defined in the long-term monitoring plan for this site.

3.1.4 Cover Design

The Technical Assistance Contractor's design of radon barrier cover over the stabilized tailings pile consist of a 7-foot thick earth cover topped by a

6-inch thick gravel layer and a rock layer. The rock layer is one foot thick on the top and 1.5 feet thick on the side slopes. Both soil and rock are available in the designated borrow sites, adjoining the tailings disposal site. The staff has reviewed the exploration data, laboratory test results, calculations for radon barrier design, and construction criteria presented in the RAP and DSCR to assess various aspects of the soil cover design.

The Remedial Action Plan (Reference 1) identifies the radon barrier earth cover soil to be a silty sand. The specifications (Reference 4) accompanying the contract documents identifies the radon barrier earth cover soil to be a sandy silt, and specifies that the portion of the soil finer than the No. 200 U.S. Standard Sieve should be greater than 50 percent. The NRC staff comments based on review of DOE's radon cover design has been transmitted to DOE (Reference 5). However, the radon barrier cover thickness design calculations by the Remedial Action Contractor, Morrison-Knudsen (MK), indicate a required average thickness of 8 feet. The Technical Assistance Contractor's staff has indicated during telephone conversations that these design differences have been reconciled, and the NRC staff has requested that the calculations pertinent to the reconciled design be presented for review. The NRC is awaiting this information. The staff is also awaiting the DOE's response to concerns raised in letter of May 15, 1985 (Reference 6), on rock sizing of the erosion protection features of the design. The staff considers the radon cover design to be an open issue pending the NRC staff review of requested information and the resolution of the items mentioned above.

3.2 Stability of Arroyo Slopes

The remedial action proposed to stabilize the Arroyos consist of: (1) modification of the top of the escarpment to drain surface-water runoff away from the edge and toward the embankment perimeter drain ditch; and (2) fill and recompaction of erosion gullies in the escarpment edge. The erosion gullies will be filled with compacted pit run gravel to a final slope of 2 horizontal to 1 vertical. The top of the filled erosion gully will be capped with a seepage barrier (1-foot thick layer of compacted Mancos shale) overlain by a 1-foot thick layer of compacted pit run gravel. The top will be sloped to drain the surface-water runoff away from the edge. This escarpment is nearly 300 feet away from the toe of the tailings pile; therefore it is not expected to pose a radiological hazard, even if there is a failure. The DOE states and the staff concurs that the slope or face of the remedied arroyos will be stable under both short term and long term design conditions.

4.0 GEOTECHNICAL CONSTRUCTION CRITERIA

The RAP presents general criteria for the excavation, fill placement, and compaction items associated with this project (Reference 4). The staff has reviewed the presented criteria and find them acceptable and consistent with standard engineering practice. Additional details of construction and quality control are yet to be submitted. The staff considers the quality control aspect of the radon barrier cover construction to be important and intends to review this information.

5.0 CONCLUSIONS

Based on a review of the reported geotechnical engineering aspects of the remedial action plan to stabilize the tailings present at the Shiprock site, the staff concludes that the slope stability aspects of the plan are consistent with the EPA standards with respect to long term stability. This conclusion is conditional upon a finding that the maximum ground acceleration due to the maximum credible earthquake for the site will not exceed 0.13g. The staff review of the radon barrier design calculations remain an open issue at this time.

6.0 REFERENCES

1. Letter dated December 14, 1984, from J. Themelis of DOE to L. Higginbotham of NRC; transmitting three documents - (1) Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings site at Shiprock, New Mexico, Revised Final, December 1984, (Vol. I, II, & III); (2) Shiprock Remedial Action Plan and Site Conceptual Design, NRC Comments, September 6, 1984, and DOE Responses, December 7, 1984; (3) Shiprock Remedial Action Plan and Site Conceptual Design, NRC Comments, October 4, 1984, and DOE Responses, December 7, 1984.

2. CSU (Colorado State University), 1982, Draft - Characterization of Inactive Uranium Mill Tailings sites: Shiprock, New Mexico.

3. CSU/HGCC (Colorado State University), 1983, Appendix A,, CSU/HGCC Report, Interim Draft, Shiprock Tailings Site.

4. Letter dated December 10, 1984, from R.E. Hopkins of Morrison-Knudsen Company, Inc., to L. Higginbotham of NRC; Subject: Shiprock Site - Shiprock, New Mexico - Phase II Construction-Preliminary Contract Documents and Design Calculations.

5. Letter dated May 17, 1985, from L. Higginbotham of NRC to J. Themelis of DOE, transmitting NRC's comments on Shiprock Construction Documents.