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Engineers Report

Report 2
Tailings Abandonment & Stabilization

Split Rock Mill
Jeffrey City, Wyoming

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3.0 ABANDONMENT AND RECLAMATION

3.1 ABANDONMENT ALTERNATIVES

Several alternative abandonment plans were evaluated on the basis of technical feasibility and of cost-benefit comparisons (construction cost versus reduction in radon emission and direct gamma radiation). Of the six alternatives initially considered, three were rejected and not studied further in detail. For the remaining three alternatives, technical and cost-benefit comparisons were made to develop the recommended plan.

3.1.1 Alternatives Presented

The three alternatives initially considered, but quickly rejected with obvious technical or cost-benefit deficiencies included:

- Cementation of tailings by admixtures to the slurry.
- Haulage of dried tailings to the worked-out mine and disposal in a lined pit.
- Chemical removal of radioactivity in the tailings, prior to disposal.

Cementation of tailings by addition of a solidifying agent into the tailings flow stream was rejected for several reasons. The low pH of the slurry would require that the slurry be treated with a neutralizing agent prior to the addition of a cementing agent (Calcilox or similar). The entire treatment and cementing cost would at least be $30 to $50 million in 20 years based on current cost for these chemicals (f.o.b. job site). Although cementing agents have been used successfully on scrubber sludges, their effectiveness on acidic tailings has not been demonstrated. Further research, test plot assessments or other state-of-the-art work is required prior to further consideration of the scheme. A reduction in material costs, in-plant neutralization of slurry water, or other advancements in technology may make this scheme viable within the 20 years to abandonment. It is not viable by present day evaluations.

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Haulage of dry tailings to the worked-out mine for disposal in a lined pit presents several serious technical and environmental drawbacks. As dried tailings were loaded and transported, fugitive dust in mill areas and along the haul road would increase significantly. The disposal pit would have to be lined and covered to meet pollution control standards at a substantial cost. Haulage cost would be extremely expensive - at least $20 million. Without further technical or cost evaluations this scheme is not comparable to other evaluations.

Chemical removal of radioactive elements from the tailings prior to disposal would require lime additives to raise the pH of the slurry followed by precipitation of thorium and radium by barium chloride treatment. The costs for these additional treatments would be large. In addition, a large quantity of tailings are already spoiled on the site. This method would not be effective in solving the abandonment problem of these tailings.

3.1.2 Alternative Considerations for Further Study

The three alternatives that were retained and studied in greater depth all involve regrading approximately 230 acres of tailings, covering the area with locally available borrow, and establishing vegetation. Thickness and type of soils vary for each alternative. In all cases, a layer of soil suitable for the establishment of vegetation will be required.

The first alternative involves covering the graded embankment entirely with local soil (dune sand) to a depth sufficient to reduce radon emanations to the required two times background level and reduce direct gamma to essentially bakcground. The maximum cover thickness would be 20 feet. The borrow sources of the dune sand would be the center portion of the north one-half and nearly all of the south one-half of Section 11, T29N, R92W, up to one mile southwest of the mill, and other dunes on or near the mill property as shown in Figure 6. Additional dune sand could be borrowed from locations further away if required. In 1977 dollars this method would cost approximately $400,000 per foot of soil placed. For the maximum 20 feet, a cost of near $8 million would be required.

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The second alternative consists of placing a clay cap over the tailings and covering the cap with a soil cover. This alternative could be subdivided into several alternatives by variations in clay cap or soil thickness. The cap would be constructed of clayey material from the Cody Shale, which crops out in the hills surrounding Crooks Gap about 10 miles south of the mill as shown in Figure 6. Properly compacted, a nominally one-foot-thick cap and six feet of soil should provide significant reduction in radon emanation and direct gamma reduction although variation in the depth of cover is possible based on test plot results. The Test Plot Program is detailed in Section 4.0 of this report. The cost of the one-foot-clay cap and six-foot soil cover is estimated to be about $4 million in 1977 dollars.

The third alternative involves covering the graded embankment with a membrane sealer and dune sand. A membrane of 20 or 30 mil PVC typically used as impermeable pond liners was considered. The soil cover would be required for membrane protection and to support vegetation. Assuming that the membrane would provide sufficient reduction of radon emanations and direct gamma radiation by itself, a soil cover not more than 4 to 6 feet would be adequate to sustain revegetation. The 1977 dollar installed cost of the membrane and soil cover is estimated to be about $4 million for 20 mil PVC and about $5 million for 30 mil PVC.

3.2 COMPARISON OF ALTERNATIVES

The following criteria were used to compare the above three alternatives:

- Effectiveness in reducing radon emanations and direct gamma radiation (benefit)
- Construction costs (cost)
- Cost-benefit ratio
- Adaptability to improving technology
- Efficiency in the use of resources
- Related environmental impacts

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3.2.1 Projected Radon and Direct Gamma Radiation Reduction at Abandonment

Measured radon emanation rates and radium concentrations at the tailings disposal site average 17.64 pCi/m^2sec and $8 \times 10^{-2} g/10^6 kg$, respectively. Direct gamma radiation measurements are 1.75R/year. These values are much lower than those assumed for the Bear Creek facility or other values reported in the literature. The average background radon emanation rates and radium concentrations for cover soils in the area are 1.21 pCi/m^2sec and $2.75 \times 10^{-3} g/10^6 kg$, respectively. Based on these measured values, calculations were made to determine the types and quantity of cover which would be required to reduce the radon emanation rate to twice background and the direct gamma radiation rates to essentially background. While soil cover alone is feasible to reduce radon emanations and direct gamma radiation, only alternatives which included a clay cap were considered at this stage. The clay cap was considered essential to preclude the percolation of surface water through the tailings pits, while aiding in radon and gamma reduction. Membrane covers would also reduce percolation but their effectiveness in radon and gamma reduction is not proven.

Figure 7 shows the radon emanation with various combinations of clay and soil covers. The radon reduction was determined by a D'APPOLONIA computer model specifically formulated to assess radon emanation reduction through porous media. Twice background radon levels can be achieved with one-half foot of clay and 5-1/2 to 6 feet of soil. It should be noted that the R (relaxation length) value used for the clay is 3.5 as opposed to the value of 1 which appears to have been used by NRC in its calculations for Bear Creek and Lucky Mc. This conservative value was used because data were not available at this time to provide an actual value. The value will be recalculated and new calculations of cover made when the data become available. This may lead to a requirement for less soil cover.

The direct gamma radiation is expected to be less than 4 mr/year (not considering background) for the least soil cover depending on the degree of compaction of the soils, as determined by calculations based on the capabilities of these soils to reduce gamma radiation. This level is essentially background when considering the direct gamma radiation for the natural soils. Background is estimated to be less than 100 mr/year (Eisenbud, 1973).

Because the radium concentration in this particular tailings pile appears to be lower than those generally found in similar facilities, a test program will be conducted to determine reclamation requirements, radon flux values and direct gamma radiation under various cover conditions. The overall program is discussed in Section 4.0 of this report. During the field test program, the following radiological parameters will be measured:

- Radon Flux
- Gamma Radiation
- Radon Emanation Coefficient
- Radium Concentration

The field measurement of these parameters under various cover conditions will make it possible to design final abandonment which optimizes radon emanations at the least possible cost.

3.2.2 Costs

The construction costs presented in Section 3.1.2 can easily be compared. Covering with only dune sand as discussed in the first alternative is extremely expensive if the full 20 feet is required. Covering with a clay cap and soil is the least costly of the three schemes although the membrane covering is not significantly more costly. The largest variation in cost or potential cost savings appears to be in the reduction of the soil cover on the second alternative (clay cap and soil cover).

3.2.3 Cost-Benefit Ratio

The cost-benefit comparison is the clearest distinction between the three alternatives. The present day estimated costs for the three alternatives are discussed above. The membrane-soil cover alternative provides virtual isolation of the tailings from vadose water and from radon emanations if the membrane seal is effective. All of the schemes provide adequate reduction in direct gamma radiation. However, the clay cap-soil cover combination provides a more dependable seal at a cost that is equal to or as much as 30 percent less than the cost of the membrane-soil cover combination. In addition, the effectiveness of the clay cap can be increased by placing any incremental thickness of clay or soil, and the cost can be decreased by reducing these thicknesses. Membrane increased effectiveness or reduction in cost can be achieved only by variations in the number or thickness of membranes placed.

3.2.4 Adaptability to Improving Technology

With final abandonment still 20 years in the future, important advances in radon containment technology are likely to develop before abandonment is fully implemented. Therefore, the abandonment plan should be flexible enough to adapt to and incorporate improvements. On this criteria all three alternatives compare favorably. None of the three require major expenditures in the near future, and all of them can be modified easily. The thickness of soil cover or clay cap and the type and thickness of membrane can be changed to accommodate improvements without cost penalty.

3.2.5 Efficiency in the Use of Resources

The three alternatives or variations thereto are similar when compared by the criteria of efficient use of resources. The soil cover and clay cap-soil cover methods use locally available materials which have little value for other purposes. The membrane alternative does involve an energy-intensive manufactured product, but it compensates somewhat with lower net transportation costs and fuel demands. The alternatives using earth materials have an additional advantage in effective use of equipment. The soils can be excavated, hauled and stockpiled for later use when mine equipment is not being used for other purposes and would otherwise be idle. Between the two earth materials alternatives, the clay cap-soil cover method has an additional advantage in that it requires a smaller total volume of material.

3.2.6 General Environmental Considerations

Some negative environmental impacts are inevitable with any abandonment plan involving excavation and hauling of earth materials. Generation of