RECENT DEVELOPMENTS IN DISPOSAL AND ISOLATION OF URANIUM MILL TAILINGS UNDER THE UMTRA PROGRAM

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ABSTRACT

Final design and construction of isolation systems for abandoned uranium mill tailings at 24 sites in 10 states is in the fourth year of a 7- to 10-year program. Construction is complete at two sites, and long-term surveillance and maintenance procedures are underway. Construction is in progress at two additional sites, and design at four others. The systems must be designed to be effective for 1,000 years, to the extent reasonably achievable, and for at least 200 years in any case. Also, the design is to rely on passive systems rather than scheduled maintenance. These requirements mean designing to the limit of technology, and in some cases advancing the state-of-the-art. This paper discusses the following previously unpublished developments: 1) optimization of radon barrier thickness during construction (Shiprock Site) using final distribution of radioactive materials; 2) application of the results of experiments testing resistance of riprap to sheet flow conditions; 3) design of ditches for overflow conditions; 4) prediction and monitoring settlements of slime-sand systems; and 5) implementation of post-construction surveillance and monitoring programs.

INTRODUCTION

Environmental isolation systems designed for the Canonsburg and Shiprock sites [part of the Department of Energy (DOE)'s Uranium Mill Tailings Remedial Action (UMTRA) Project], have been completed and constructed. Each system is designed to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years; and to rely on passive systems rather than scheduled maintenance. The finished systems at Canonsburg and Shiprock are shown in Figs. 1 and 2.

In developing the long-life designs constructed, it has been necessary to make design adjustments and monitor settlements during construction, and to implement a post-construction surveillance and maintenance program to confirm that design objectives were achieved. It has also been necessary to develop procedures that advance the state-of-the-art. Design adjustments and programs involved include: finalization of radon barrier thickness, monitoring of settlements during construction, and post-construction surveillance and maintenance. Technology developments include: identification of riprap design procedures and accommodation of extreme event runoff using erosion resistant aprons. These design adjustments, programs, and technology developments are described in this paper.

POST-DESIGN ADJUSTMENTS AND PROGRAMS

Radon Barrier Thickness

Each isolation system is designed to limit the transmission of radon-222 from the tailings into the atmosphere to not exceed an average release rate of 20 pCi/sq. m/sec. This is accomplished by providing a cover layer of compacted clay, as shown in Fig. 3. The thickness of this layer is calculated using equations developed by Rogers and Neilsen (1). A key variable in the equations is the average radium-226 content in the upper 10 feet of tailings lying just below the clay layer. Because the identification of the particular tailings to be placed in this location depends on progress and developments taking place during construction, it is generally necessary to recalculate the thickness requirement as the final data on radium-226 concentration become available near the end of construction.

The application of this procedure at the Shiprock (NM) site illustrates the potential interaction of design and construction. For bidding purposes, the design indicated that the clay layer would have a uniform thickness of seven feet over the entire 70-acre tailings embankment. For construction practicality, placement of the clay layer on the side slopes began before placement of

Fig. 1. Completed Tailings Deposit at Canonsburg, PA

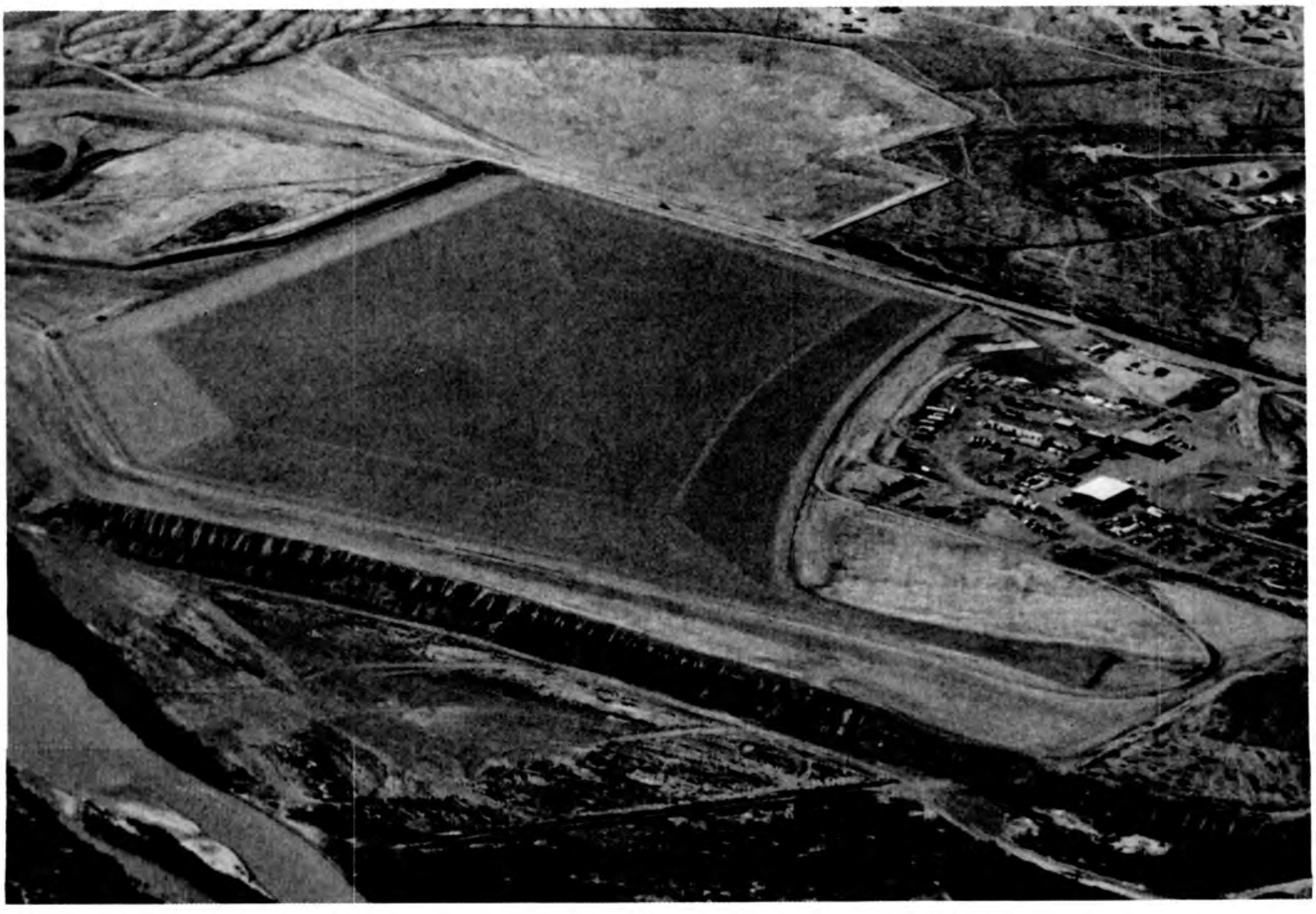

Fig. 2. Completed Tailings Deposit at Shiprock, NM

tailings on the top of the pile was completed, and, therefore, before the final radium-226 values were available. Consequently the thickness of clay on the sides was left at seven feet, and the thickness on the top was adjusted to meet the design limit for the average radon-222 rate transmission for the entire pile. The resulting thickness on the top was 6.4 feet.

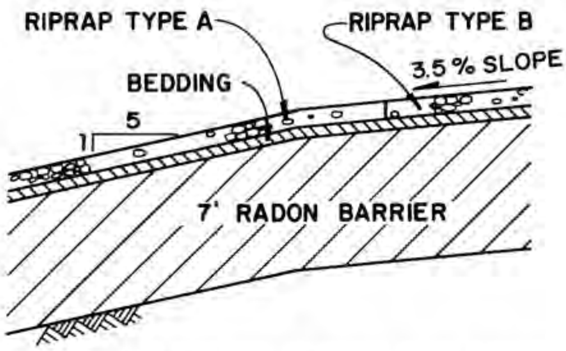

Fig. 3. Typical Tailings Isolation Cover System

Construction Period Settlements

At many sites, layers of fine-grained tailings ("slimes") are subjected to increased vertical loads as additional tailings and the cover materials are placed on the embankment upper surface. The resulting settlement can be accommodated if it develops during construction. This was the situation predicted by calculations performed for the Shiprock site. Specifically, 90% of the calculated maximum settlement of 11 inches would occur within 3 months after final placement of tailings and the radon barrier. To confirm this prediction, and provide for rebuilding possible areas of settlement, 12 monuments were installed on the tailings surface, and settlements were monitored weekly. The results at Monuments No. 8 and 9, in the area of maximum settlement, are shown in Fig. 4. The average rate of settlement decreased to a negligible value during this period. The maximum settlement recorded is significantly less than predicted, probably because conservative factors were used in the settlement calculations. The apparent decreases in settlement are due to surveying variations due to excessive sight distances.

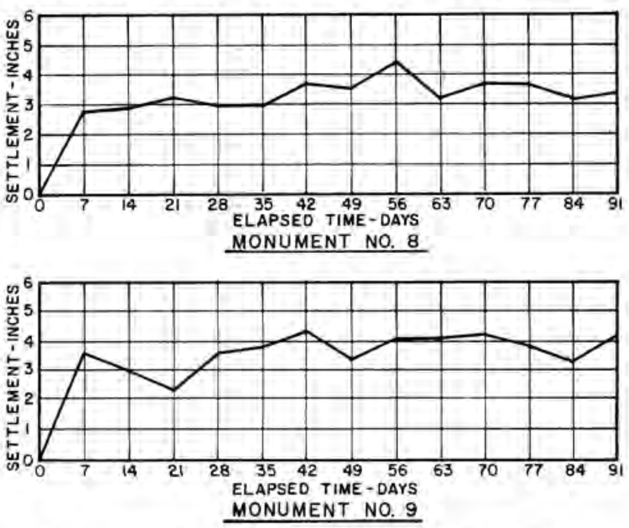

Fig. 4. Settlements at Monument Nos. 8 and 9 at Shiprock Tailings Embankment

Post-Construction Surveillance and Maintenance

Each tailings isolation system is designed to function without scheduled maintenance. As a prudent additional step, a program of post-construction surveillance is being implemented at each completed site. General guidelines are given by the DOE (2) for 1) documentation of final site conditions, 2) aerial photography and mapping, 3) warning signs, 4) settlement monitoring, 5) ground water monitoring, and 6) annual and extreme event inspections. A site-specific Surveillance and Maintenance Plan is prepared for each tailings repository, based on the DOE's general guidelines, but tailored to the local situation.

Maintenance will, of course, only be necessary in the case of unexpected changes in the integrity of the constructed facility. The post-construction monitoring program provides for this possibility. A typical inspection check list is presented in Table I.

TABLE I

Inspection Check List for Monitoring Program

- Unforeseen subsidence of the embankment or its foundation.
- Gullying that has cut through or is threatening to cut through the outer cover.
- Slides on the slopes of the site.
- Indication of rapid deterioration of the rock barrier.
- Change in position of an adjacent stream channel.
- Indications of rapid headward cutting of a nearby arroyo.
- Cracks that extend deeply into the embankment (more than six inches).
- Presence of animal burrows on the site.
- Invasion of shrubs or trees onto the site.
- Removal of some of the site material.
- Seepage.

UMTRA TECHNOLOGY DEVELOPMENT

Riprap Design Procedures

As shown in Fig. 3, the clay radon barrier is protected from erosion by a layer of riprap designed to resist runoff from the probable maximum precipitation (PMP). The procedures available for determining the size of riprap particles required to resist runoff flow from the PMP include the Safety Factors Method (3) and the Stephenson's Method (4). At the beginning of the UMTRA program no specific limits on the applicability of these methods to the analysis of flow over the surface of a riprap layer were known. Therefore, calculations were performed using both methods, the assumption being made that one method would check the other.

Early in the program, it was noted that for the sheet flow conditions expected on the top and sides of a tailings embankment, the Safety Factors Method gave rock sizes considerably larger than the sizes calculated using the Stephenson's Method. This difference had important economic consequences, as the rock sizes were usually large enough to significantly affect the riprap layer thickness, and thus the riprap layer cost. Therefore a program of large-scale tests of the effects of sheet flow over riprap at various slopes in flumes was undertaken at Colorado State University (5). The research discovered that for slopes of 10% or greater the rock sizes predicted by the Stephenson's Method were still conservative (even though smaller than the sizes calculated using the Safety Factors Method). Because sufficient conservatism is built into the use of the Stephenson's Method, it was adopted as satisfactory for design for slopes of 10% or greater.

For slopes of less than 10%, the Stephenson's Method was less conservative, and for slopes of less than than 5%, it appeared to be nonconservative. The Safety Factors Method remained conservative even for slopes as flat as 1%. Therefore, as a safe procedure, it has been decided to use the Safety Factors Method for all slopes of less than 10%.

Erosion Resistant Aprons

The first tailings isolation system designed under the UMTRA Program was for the Canonsburg Site in western Pennsylvania. It happen to be one of the smallest embankments (155,000 cubic yards), and a satisfactory runoff collection scheme using rock-lined ditches along the toe of the embankment was designed. (See Fig. 1.) Nevertheless, the flows developed under PMP conditions were substantial, and the corresponding riprap requirements were large (22-inch maximum size). It was appreciated that for the larger embankments to be designed as the program proceeded, ditch and rock sizes could increase to impractical dimensions unless a different approach was developed.

As an alternative to the collection of runoff in large, rock-lined ditches the decision was made that where permissible the sheet flow coming down a given side of an embankment would be slowed at the toe by passing the flow across an erosion resistant (rock-lined) apron where the slope could be gradually reduced. The apron would extend a sufficient distance to reduce the flow velocity to a point where it could be transferred to the surrounding landscape without causing environmental damage.

Where discharge of all flows in the manner described above is not permissible (such as along one side of the Shiprock pile, where a road could be affected), a ditch capable of containing runoff from all storms up to a certain recurrence interval (say up to the 100-year storm), but designed to allow the excess runoff from rarer larger storms to overflow the ditch onto an apron of the type described above, would be prescribed. This was done at the Shiprock site, resulting in a satisfactory, practical design.

CONCLUSION

The following developments in the disposal and isolation of uranium mill tailings have been discussed: 1) construction period adjustment of the thickness of the clay radon barrier used to cover a uranium mill tailings pile based on radium concentrations in the final 10 feet of tailings; 2) monitoring of and adjustment for load-induced settlements that could affect cover behavior; 3) post-construction surveillance, including aerial photography, ground water monitoring, and annual and extreme event inspection; 4) restriction of the Stephenson's Method of riprap design to slopes of 10% or greater; and 5) transfer of sheet flow from an embankment side slope and PMP overflow from a ditch designed for a 100-year storm across a rock-lined apron.

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