URANIUM TAILINGS RECLAMATION - REGULATIONS, DESIGN AND CONSTRUCTION

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ABSTRACT

The design and construction of systems to clean up or stabilize designated tailings sites are governed by numerous environmental regulations and technical guidelines. Design criteria have been established to fulfill these regulations and guidelines. A compacted soil cover, a radon barrier, will inhibit radon emanation and will prevent groundwater contamination in conformance with the regulations. To provide environmental protection during the construction of the isolation system requires a variety of federal, state and local permits, approvals and notifications. Temporary features that provide the necessary environmental protection during construction include flood control berms, intercept ditches, sediment control facilities, and evaporation ponds or wastewater treatment facilities.

The remedial action recently completed at the Uranium Mill Tailings Remedial Action (UMTRA) site at Canonsburg, Pennsylvania has shown that the design for the isolation of tailings may need to be adjusted in response to unforeseen site conditions that develop during construction. However, this experience also demonstrates that the construction of a waste isolation project can proceed to a successful conclusion and satisfy basic regulatory requirements.

INTRODUCTION

When uranium ore is crushed and subjected to extraction processes, waste sands and slimes are formed and discarded as mill tailings. Uranium mill tailings, which contain residual amounts of radioactive material, can prove to be a radiation health hazard. The uranium left in the tailings will decay to radioactive elements including radon, a radioactive gas. Radon can be easily dispersed by air currents. In addition, radioactive elements can be leached out of the tailings into the groundwater. Long-term inhalation of radon gas or ingestion of contaminated water can increase the risks of certain types of cancer. To address these problems, and to prevent the movement of tailings offsite by human, animal or natural forces, the U.S. Congress passed the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604). This law requires that the U.S. Department of Energy (DOE) perform remedial actions for tailings located at 24 abandoned uranium processing sites.

Remedial actions implemented at a given tailings site must meet standards set by the Environmental Protection Agency (EPA). Each remedial action site must be licensed by the Nuclear Regulatory Commission (NRC) as having been designed and constructed to meet EPA Standards. In addition, the construction process itself must be carried out in an environmentally safe manner by satisfying state and local regulations.

REGULATIONS AND GUIDELINES

Permanent Features

EPA standards for cleanup and control of designated uranium mill sites are contained in Title 40, Part 192 of the Code of Federal Regulations. The EPA regulations require that environmental controls rely on passive systems; such systems require no scheduled maintenance to ensure their integrity. The regulations also require that control systems be effective for up to 1000 years, to the extent reasonably achievable, and for at least 200 years in any case. The objectives of the controls are to prevent removal of tailings from the disposal site, protect the groundwater, and minimize the release of radon gas. Control systems must be designed to provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not exceed an average release rate of 20 pCi/ sq. m./sec.[a], or increase the annual average concentration of radon-222 in the air at or above any location outside the site by more than 0.5 pCi/l.

Groundwater protection measures are determined on a site by site basis, relying on relevant state and federal criteria for anticipated or existing uses of the water and by the EPA hazardous waste management criteria (47 FR 32274).

The controls can involve consolidation and stabilization of the tailings at the existing tailings site or transfer of the tailings to a new disposal site. When tailings are relocated, the original tailings site can be returned to unlimited public access if remaining radium-226 averaged over any area of 100 square meters does not exceed the background level by more than 5 pCi/g averaged over the first 15 cm of soil below the surface, and 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below the surface.

Construction

The following environmental and public health controls must be satisfied during construction: protect against releases of contaminants from the site; minimize worker and public exposure to contaminated materials; and provide flood protection, runoff and sediment control, and treatment of wastewater. Specific regulations regarding flood protection and wastewater discharge are:

1. Permanent Program Performance Standards, Part 816, Subchapter K, of the Office of Surface Mining. These standards give the performance requirements for sediment control measures, diversions and channels.

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[a] 1 picocurie = 10^{-12} curies;
1 curie = 3.7×10^{10} disintegrations per second.

2. The National Pollution Discharge Elimination System (NPDES). This system establishes discharge water quality limits on a site specific basis.

DESIGN

Permanent Features

The choice between on-site isolation of tailings and removal for isolation elsewhere is based primarily on the ability of meeting EPA standards at the current location. Choosing between acceptable sites is then a question of economics. Cost considerations include the amount and type of surface water control needed, the volume of tailings to be moved, the volume of cover and erosion protection materials required, and haul distances. Conceptual designs are prepared to facilitate environmental and cost comparisons for the selection of the disposal site and the approach to be implemented.

Uranium tailings isolation requires controlling the rate of radon release from the tailings, protecting the radon barrier from erosion, and limiting contamination of the groundwater. Current technology favors a compacted soil cover for the radon barrier. The rate of radon release is evaluated using a procedure developed by Rogers and Nielson[2]. This procedure is used to determine the soil layer thickness required to avoid exceeding the allowable flux limit of 20 pCi/sq. m./sec. The soil layer is protected from erosion by overlying layers of bedding and riprap. A typical cover cross-section is shown in Fig. 1. The design precipitation intensity is determined using hydrometerological reports by the National Oceanographic and Atmospheric Association (NOAA)[3]; the rock size for sheet flow is determined by Stephenson's Method[4]; and the rock size for ditches using the Safety Factors Method[5]. A portion of the site precipitation will infiltrate into and through the tailings. The rate of infiltration and the effects on groundwater levels and water quality are estimated using theoretical models[6,7,8,9].

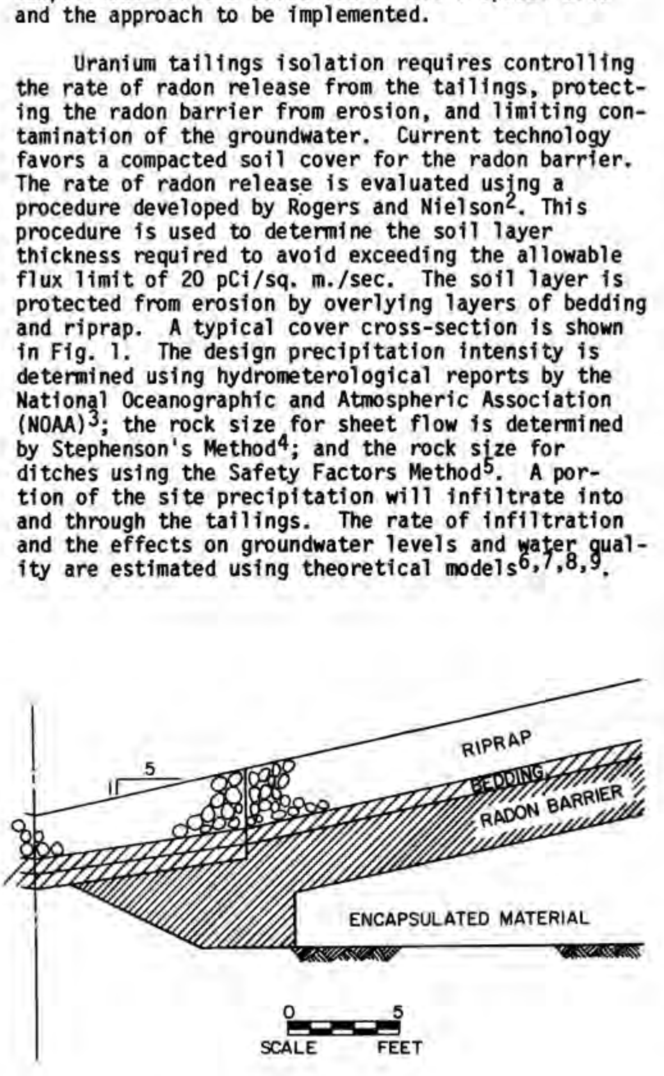

Fig. 1 Cross-section at Edge of Typical Encapsulation Cell.

The regulatory requirement that controls be effective for 200 to 1000 years without relying on maintenance significantly increases the number of potentially threatening phenomena to be considered in design. Environmental aspects such as climatic changes and glaciation, which would not be important to projects with a more typical design life of 20 to 40 years, must be considered. A list of design considerations is presented in Table I. Several of these considerations are discussed after Table I to illustrate the interaction of regulations and design.

TABLE I
Design Considerations -
Reclamation of Uranium Tailings
200 to 1000-Year Design Life

1. Animal Burrowing	13. Groundwater Fluctuation
2. Capillary Rise	14. Human Alteration of Systems
3. Chemical Alteration	15. Mining
4. Climatic Changes	16. Radiological Decay
5. Desication/Cracking	17. Root Penetration
6. Earthquakes	18. Settlement
7. Erosion	19. Slope Failure
8. Extreme Winds	20. Stream Meander
9. Fire/Pestilence	21. Volcanic Activity
10. Flooding	22. Weathering
11. Geothermal Activity	
12. Glaciation	

The radiological decay chain includes the ingrowth of thorium 230 into radium 226, the parent of radon-222. The thorium concentration of the tailings must therefore be determined, and the rate of change of thorium to radium during the 200 to 1000 year design life must be accounted for in the design of the radon barrier.

The materials selected for the radon barrier and erosion protection layers must be chemically and physically stable over the specified design life. This narrows the choices to natural materials, as man-made materials do not have the exposure history necessary to document long term stability. Furthermore, for the erosion protection materials, evidence must be obtained to indicate that the rock will resist weathering over the periods in question.

Stream meander may pose a direct threat to a given site and, in some cases, may eliminate the site from further consideration. In other cases, such as at the Canonsburg, Pennsylvania site, it may be possible to design for prevention of stream meander by including a riprap wall between the stream and the encapsulated tailings cell. As shown in Fig. 2, the wall at the Canonsburg site was located some distance from the stream to minimize the area to be protected.

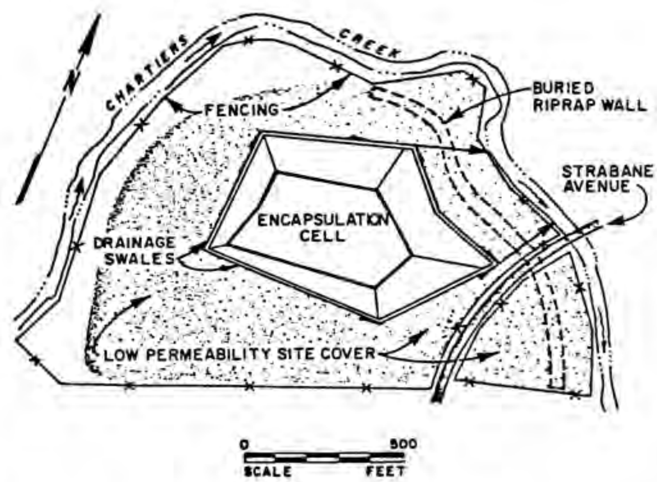

Fig. 2 Permanent Site Features at Canonsburg Site.

Construction Facilities

Ensuring an environmentally safe construction operation begins with the design. In addition to the general guidelines and regulations cited above, detailed criteria are established by the DOE[10] and various federal, state and local permitting agencies. Design criteria are developed for construction facilities such as flood control berms (if necessary), runoff collection ditches, sediment control features (silt fences and possibly a sedimentation basin), wastewater treatment or evaporation facilities, equipment and materials storage areas, borrow areas and haul roads, and radiation monitoring and decontamination areas.

Public assurance of environmental protection is achieved by fulfilling the requirements of various state and local permits, approvals and notifications. Table II presents a list of permits, approvals and notifications for the Canonsburg site, which is a typical UMTRA site. Development of such a list for a given site should be accomplished early, since the processing time for certain permits may influence the bid solicitation schedule.

TABLE II
Permits, Approvals and Notifications for Typical UMTRA Site (Canonsburg)

Description	Review* Agency
Earth Disturbance Permit	PA-DER
Water Obstruction Permit	PA-DER
Part I Water Quality Management Permit - NPDES Permit	PA-DER
Part II Water Quality Management Permit - Design Engineer's Report - Preparedness, Prevention and Contingency Plan	PA-DER
Plan Review for Haul Routes	PA-DOT
State Highway Access Permit	PA-DOT
Review of Transportation Equipment Routes and Washdown Plan	PA-DOT
Well Abandonment Notification	PA-DER
Plan Review for Minimization of Fugitive Emissions	PA-DER
Notification of Demolition Involving Asbestos Materials	PA-DER

* PA-DER = Pennsylvania Department of Environmental Resources
PA-DOT = Pennsylvania Department of Transportation

CONSTRUCTION

Overview

Experience at the Canonsburg, Pennsylvania, UMTRA site illustrates the interaction of regulations, design and construction. At Canonsburg, the tailings were relocated on site. This involved excavating, stockpiling, and placement of the tailings on a capillary break and a clay liner. The tailings were covered with a clay layer and erosion protection layers. The general outline of this encapsulation cell is shown in Fig. 2. A buried riprap wall protects the cell from potential meander of the adjacent creek. The remainder of the site was covered with a low permeability soil, and the entire site was enclosed within a security fence, also shown in Fig. 2.

In order to construct the permanent features described above, it was necessary to provide the following temporary facilities as shown in Fig. 3.

- A flood control berm to protect open excavations
- A sedimentation pond for temporary storage of stormwater runoff and groundwater from excavation dewatering
- Perimeter ditches to intercept runoff and direct it to the sedimentation pond
- A wastewater treatment plant to treat water in the sedimentation pond before discharge to the creek

In addition, silt fences were used to remove sediment from runoff from uncontaminated areas of the site that did not drain into the sedimentation pond.

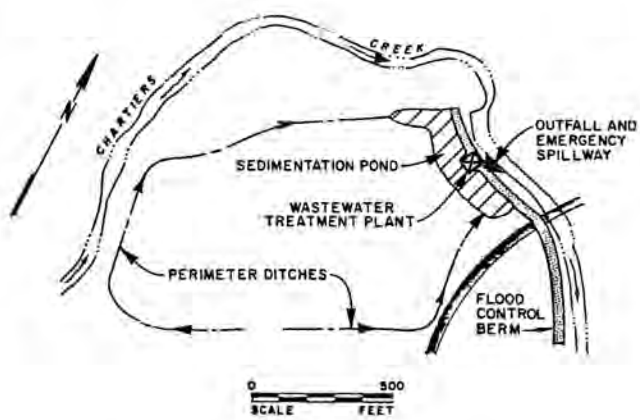

Fig. 3 Major Construction Features at Canonsburg Site.

Interaction With Regulations and Design

Some significant interactions involving regulations and design at the Canonsburg site are described below.

1. Estimated volumes of contaminated materials that would have to be excavated and placed in the encapsulation cell were included in the bid documents, with the provision that final limits would be determined by radioactivity measurements taken during contruction. The cell had been designed to provide a storage volume approximately 30 percent greater than that determined from the estimated excavation limits, to allow for additional material identified during construction. As construction proceeded,

it became evident that the final volume would be almost twice the original estimate. The cell was redesigned during construction to match the revised requirements.

2. Limits on the percentage of organics allowed in the encapsulated tailings conflicted with the need to retain all contaminated materials on site. Studies were performed leading to the conclusion that the limit could be increased, and the specifications were modified accordingly.

3. During excavation of an underground concrete vat at the former industrial facilities, it was observed that chromic acid had leaked from the vat, contaminating the soil and groundwater in the immediate vicinity. Disposal of the contaminated soil and water presented unforeseen problems. After re-examination of the design, it was determined that the contaminated soil could safely be placed in the encapsulation cell. The chromic acid was removed to a licensed disposal area and the contaminated water entering the sedimentation pond was processed through the treatment plant.

4. The prospective bidders were allowed to select their own borrow areas, subject to supplying evidence that the materials met certain limits on grain size and plasticity. The radon diffusion coefficient was then determined for the material from the borrow area approved for use. This value was used to determine if the design cover thickness should be adjusted during construction. No adjustment was needed at Canonsburg.

5. The permeability of the soil cover greatly influences the amount of precipitation that infiltrates into the tailings. Based on laboratory tests of borrow material proposed for use in the radon barrier, a hydraulic conductivity value (permeability) was selected for evaluation. A method specification of compaction was developed (moisture content, lift thickness, type, model and weight of roller, and number of passes) to produce the required permeability. The fact that the specfied soil compaction would meet the design permeability requirements was confirmed by test fills prepared as part of the construction contract.

CONCLUSION

The Uranium Mill Tailings Radiation Control Act requires that the Department of Energy perform remedial actions at 24 former uranium mill sites. The remedial actions must meet control standards set by the Environmental Protection Agency. The controls shall be designed to be effective for up to 1000 years, to the extent reasonably achievable, and for at least 200 years in any case, and to restrict the releases of radon-222 to not exceed allowable limits. The exceptionally long design life greatly increases the number of potentially threatening phenomena to be considered in design (see Table I). Ensuring an environmentally safe construction operation is the goal of permits, approvals and notifications (see Table II). Experience at the Canonsburg, Pennsylvania site illustrates the interaction of regulations, design and construction. At Canonsburg, it was necessary to adjust the design as conditions developed during construction. Remedial action at this site has proceeded successfully, satisfying the basic regulatory requirements in an environmentally safe manner.

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