CRITERIA FOR REMEDIAL WORK AT
INACTIVE URANIUM MILL TAILINGS PILES

J. A. CALDWELL,[1] T. R. WATHEN[2]
AND J. R. D'ANTONIO[3]

[1]Jacobs Engineering
5301 Central Ave. NE, Suite 1700
Albuquerque, NM 87108

[2]Morrison-Knudsen Engineers, Inc.
180 Howard Street
San Francisco, CA 94105

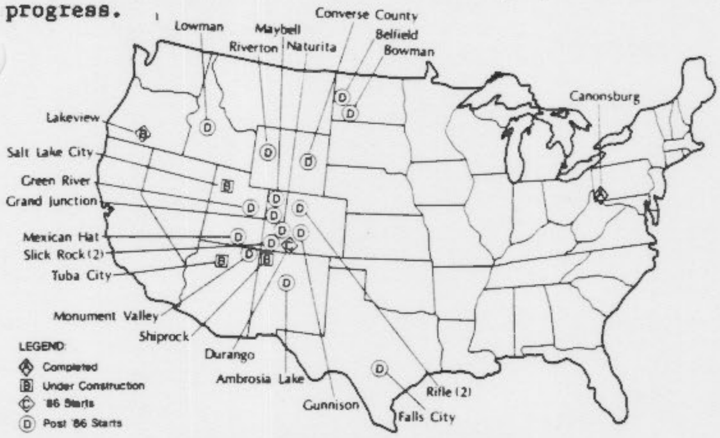
[3]Department of Energy
P.O. Box 5400
Albquequer, NM 87118

ABSTRACT

This paper is an overview of the design criteria and procedures used by the U.S. Department of Energy for remedial actions at inactive uranium mill sites in the Uranium Mill Tailings Remedial Action Project. Also included is an overview of the standard Review Plan used by Nuclear Regulatory Commission staff in reviewing proposed remedial actions.

INTRODUCTION

The U.S. Department of Energy (DOE) oversees the Uranium Mill Tailings Remedial Action (UMTRA) Project which involves remedial action work at 24 inactive uranium mill tailings deposits in ten states (Figure 1). To date, construction work has begun at three of the tailings piles, and design of the remedial work at the remaining piles is in progress.



UMTRA SITES STATUS - AUGUST 1986
Figure 1

The Uranium Mill Tailings Radiation Control Act of 1978, PL95-604, grants the Secretary of Energy authority and responsibility to perform such acts as are necessary to minimize health hazards and other environmental hazards from the inactive uranium mill sites. Standards for the project were developed by the U.S. Environmental Protection Agency (EPA) and, following completion of the remedial action, the individual sites are licensed by the Nuclear Regulatory Commission (NRC). The two primary standards for the remedial action work are that control shall be designed to:

- o Be effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years; and,
- o Provide reasonable assurance that releases to the atmosphere of radon-222 from radioactive material will not exceed an average release rate of 20 picocuries per square meter per second, or increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than 0.5 picocurie per liter.

In addition, the design is to rely on passive systems to reduce or eliminate future maintenance.

For each site, a Remedial Action Plan (RAP) is prepared to document the work to be done to bring the site up to EPA standards. The RAP is prepared by a Technical Assistance Contractor (TAC) for and on behalf of the DOE. The detailed design of the remedial work is prepared for the DOE by a Remedial Action Contractor (RAC) and is presented in the RAP. Before construction work begins, the NRC and the various states and Indian tribes in whose areas the piles are located must concur with the design of the remedial work. Concurrence is based on the design and details contained in the RAP.

At the beginning of the UMTRA Project there were no previously agreed upon site design criteria and procedures. In preparing RAPs and designs for the initial UMTRA sites there were various opinions among the parties involved on the design criteria and methods to be used. The design criteria and procedures needed to include:

- o State-of-the-art engineering practice.
- o EPA standards for cleaning up uranium mill tailings piles.
- o NRC requirements for concurrence.
- o Requirements of other concurring parties.

Resolution of the design criteria and procedures has led to the recent publication and acceptance of four major documents that describe the general technical approaches and design criteria which have been adopted. This paper describes these documents and highlights the important new and innovative aspects of the documents that pertain to the design and construction of remedial action works at inactive uranium mill tailings piles.

TECHNICAL APPROACH DOCUMENT (TAD)

The Technical Approach Document (TAD) (DOE, 1986), is published by the DOE as the authority responsible for managing the UMTRA Project. It was developed as a joint effort by the Technical Assistance Contractor and the Remedial Action Contractor.

The TAD describes the general technical approaches and methods, and also the design criteria to be adopted to implement remedial action work consistent with the general standards applicable to the UMTRA Project and acceptable to the various concurring parties to a remedial action. There are five main sections of the TAD: Pile Layout; Surface Water and Erosion Control; Geotechnical; Radon Attenuation; and Water Resources Protection. The four latter sections correspond to sections in the NRC Standard Review Plan discussed below.

The TAD was developed by working groups composed of members of the TAC and the RAC in consultation with the EPA and NRC. Drafts of the document were reviewed and commented on by the NRC, EPA, and the various states and tribes affected by the UMTRA Project. The following is a survey and discussion of the highlights and the points about which there was most discussion, or where innovative approaches are adopted.

Design Precipitation

The TAD notes that designs will be for the Probable Maximum Flood and the Probable Maximum Precipitation. Many existing uranium mill tailings piles are poorly sited: some are adjacent to streams or in major flood plains. For these sites, the PMF may be so large as to preclude economic long-term stabilization. The TAD provides for designing such piles for a lesser event if it can be shown both that protecting against the PMF is clearly impractical and that the EPA standards can be met. Factors to consider in defining "clear impracticality" include:

- o Difficulty of providing a reasonable layout.
- o Unavailability of alternative design solutions.
- o Technically unfeasible to provide for the PMF.
- o Materials that can resist a PMF are not economically available.

Erosion Protection

Emanation of radon gasses from a pile is controlled by placing a barrier of compacted, fine-grained soil over the pile. This barrier is usually protected from erosion by covering with durable rocks of sufficient size to resist erosion by the flow resulting from the PMP on the pile.

The TAD provides for use of the method described by Stevens, et al. (1976) for slopes less than 10% and for ditches. The method is commonly referred to as the Safety Factors Method; it is based on the use of the critical shear stress that initiates movement of an assemblage of frictional particles. The name of the method refers to the fact that the user chooses the Factor of Safety (FOS) and hence calculates the required rock size. On the UMTRA Project a FOS of unity is adopted for the PMP flow - for all other precipitation, therefore, the FOS is greater than one.

For slopes steeper than 10%, such as those encountered on the sides of the pile, the method described by Stephenson (1979) is used. This method takes into account the interstitial flow through the rock voids. This results in a lesser required rock size for side slopes than if the Safety Factors Method were used.

Seismic Design Criteria

Because the basic EPA standard for pile stability is a thousand years, where reasonably achievable, the following definitions of seismic design events are adopted.

- o **Design Earthquake:** the earthquake that produces the largest on-site peak horizontal acceleration or the most severe effects; this earthquake could result from either a rupture along a defined fault or a floating earthquake or both.
- o **Floating Earthquake:** an earthquake occurring within a specific seismotectonic province but not associated with a known tectonic structure. The floating earthquake within a seismotectonic structure is not less than the largest event associated with a known geological structure; it may be larger if the seismotectonic characteristics of the province indicate such a need.
- o Capable Fault: a fault with one or more of the following characteristics:
  - Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.
  - Macroseismicity determined with instruments of sufficient precision to demonstrate a relationship to the fault.
  - A structural relationship to a capable fault such that the movement on one fault could reasonably be expected to cause movement on another.

In order to determine the site design earthquake and its effect at the site, the earthquake record for all seismotectonic provinces within 200 km of the site is analyzed, and the on-site acceleration resulting from the floating earthquake in each province is calculated. The floating earthquake is placed at the closest point in the province to the site, and, from attenuation relationships given by Campbell (1982), the on-site peak ground acceleration is calculated.

For defined faults, the relationship between fault length and magnitude given by Slemmons, et. al. (1982) or Bonilla, et. al. (1984) is used to calculate on-site earthquake effects.

Radon Barrier Moisture Content

The radon barrier serves both to prevent the escape of radon from the pile and to inhibit infiltration to the tailings. Both radon attenuation and infiltration are significantly affected by the moisture content of the radon barrier. Hence, accurate determination and specificatioo for design of the radon barrier moisture content is important to accurate and cost-effective pile remedial action work.

It is recognized that variations in the moisture content of the radon barrier can and will occur over the design life of a pile. The mean value of the moisture content may be used in calculating the infiltration and the radon flux through the radon barrier. For the purposes of a conservative estimate of the radon flux and the amount of seepage through the radon barrier, however, it may be necessary to evaluate the upper and the lower values of the long-term moisture content in the radon barrier; and hence to obtain a measure of the conservatism and reliability of the design.

In order to estimate the long-term moisture content of the radon barrier, empirical and theoretical procedures are employed. In the laboratory, ASTM D2325 and D3152 methods are used to measure the relationship between moisture content and soil suction (or negative water pressure). The NRC Standard Review Plan requires that in the absence of demonstration to justify an alternate approach, the design moisture content of the radon barrier will be that which corresponds to a soil suction of minus 15 bars pressure.

Empirical correlations between the soil gradation (percent sand, silt, and clay) and moisture content for given soil suctions are given by Rawls, et. al. (1982), Brakensiek, et al. (1982), Rawls and Brakensiek (1982) and Gupta and Larson (1979). In addition various computer models that predict the soil moisture for various boundary conditions have been evaluated. To date, only the formula given by Rawls and Brakensiek (1982) is used routinely to calculate a design value of the radon barrier moisture content. The laboratory determined moisture content corresponding to minus 15 bars pressure is also used.

Aquifer Restoration

Aquifer restoration has been proposed at many of the UMTRA Project sites. The U.S. Court of Appeals, Tenth Circuit, has recently set aside the water protection portion of the Title I standards and remanded these standards to the EPA for revision. The DOE has proposed interim standards to EPA so that work on the UMTRA program may continue. To date no restoration programs are planned, although evaluations are still in progress for some sites. The TAD provides for consideration of the following factors in assessing the viability of aquifer restoration: effectiveness, cost, volume of contaminated water, removability of contaminants, and treatability of the water. In addition, the following procedure is normally adopted:

- o Perform risk analysis of the effect of not implementing aquifer restoration and the potential for reducing or not reducing adverse health impacts from water contamination.
- o Develop a list of potential protective and restorative alternatives.
- o Evaluate the technical feasibility of the alternatives.
- o Perform a cost benefit analysis of the alternatives.

Alternatives to ground-water or aquifer restoration that are considered include:

- o Cover tailings with low permeability clay. (The radon barrier normally does this.)
- o Divert water away from and off the pile.
- o Construct slurry wall and grout curtain.
- o Move tailings to alternative locations; or pump ground water to restrict or withdraw contaminants.
- o Treat water in-situ or before reinjection.

TECHNICAL STANDARD OPERATING PROCEDURES

These documents are prepared by the Technical Assistance Contractor for the DOE. The documents describe the standard procedures used to collect, analyze, and record and interpret data. Also, they describe methods for documenting work. The data must be interpreted by planners, designers and review agency staff, hence the operating procedures to be applied at all steps of the process are stringent.

Table 1 lists the Technical and Engineering Standard Operating Procedures compiled for the UMTRA Project. Most apply to field data collection, particularly ground-water procedures. The methods prescribed for use in the Standard Operating Procedures are standard in the industry in which they are applicable, and hence are not described or discussed in detail herein. The procedures adopted have been approved by the parties involved in the UMTRA Project.

TABLE 1: STANDARD OPERATING PROCEDURES

Technical Data Acquisition and Data Quality Assurance
Horizontal and Vertical Control (Site Coordination System)
Topographic Surveys
Legal Surveys
Borehole Test Pit Logging Including Soil Sampling
Drilling Procedures
Monitoring Well Installation
Well Development
Water Sampling/Preserving/Shipping and Testing
Slug Testing
Packer Testing
Aquifer Pump-Out Testing
Standard Location Identification for Test Borings, Test Pits, and Monitoring Locations
Soil Water Sampler Installation and Use
Soil Sample Routing
Installation/Servicing of Tensiometers and Measurement of Soil Water Potential
Handling and Shipping of Geotechnical Samples
Completing the Daily Field Activity Report
Borehole Geophysical Logging
Trenching Procedures During Fault Studies
Piezocone Testing
Water Sampling for Tritium Analysis
Data Reporting Formats and Protocols
Data Entry, Validation, and Archiving the Technical Data Base Management System
Lithologic Modeling
Laboratory Testing of Borehole Samples of Rock and Soil
Evaluation of Chemical Analysis of Water Samples

DESIGN PROCEDURES DOCUMENT

This document (MKE, 1986) was published by the Remedial Actions Contractor for two purposes:

1. To provide guidelines for the design of remedial actions at UMTRA sites, assuring design consistency where appropriate. Development of imaginative, creative and more efficient solutions is not to be discouraged by publication of these guidelines.

2. To document the design procedures used at UMTRA sites, facilitating design reviews.

The procedures included in the document are based on state-of-the-art design methods and current design criteria. The procedures will be changed when necessary to ensure that the methods remain current.

Consistent application of the methods presented will result in reasonable assurance that the designs will meet the design life requirements of 200 to 1,000 years, with minimum maintenance.

There are four main areas covered by the Design Procedures Document: Pre-Design Activities; Site Drainage and Erosion Protection; Radon Barrier Design; and Settlement, Stability and Liquefaction Analyses.

Pre-Design Activities

Data collection and review are basic to design. In preparation for development of preliminary and final designs for a given site, the following documents prepared by the TAC under the direction of DOE are reviewed:

- o Processing Site Characterization Report (PSCR)
- o Disposal Site Characterization Report (DSCR)
- o Environmental Assessment (EA) or Environmental Impact Statements (EIS)
- o Draft Remedial Action Plan (RAP), including calculations and the Site Conceptual Design (SCD)
- o Studies by universities and research institutions, especially under grants from the USAEC, ERDA, NRC or DOE
- o Aerial reconnaissance studies, including aerial photographs
- o Topographic maps

Additional investigations will only be needed if unusual conditions are discovered during the data review process described above. Some circumstances under which additional investigation may be required are:

- o A new disposal site is selected.
- o A new borrow area is selected.
- o The need for re-establishing the contaminated materials boundary has been identified and a larger scale or more detailed topographic map (1 inch = 200 ft each and 1- to 2-foot contour interval) is required.
- o There is a lack of adequate air and water quality data (surface and subsurface) required for permit applications.
- o Aerial photos, satellite photos, or ERTS imagery of the site area and vicinity, are needed to locate lineaments or suspecred faults.
- o Historic earthquake data from the NOAA Earthquake Data File are needed.
- o Additional data on the contaminated tailings in place may be needed. For example, the PSCR may indicate there are large deposits of potentially weak and highly compressible slimes within the tailings piles.

Site Drainage and Erosion Protection

The design storm for permanent drainage features and erosion protection design is the Probable Maximum Storm, or lesser events where appropriate, as described above under Technical Approach Document. Construction drainage facilities, such as ditches and retention basins, are generally designed for the 10-year, 24-hour storm, though the 25-year storm may be required for sites at certain locations. Ditch capacities are determined using one of the following methods to calculate peak run-off:

Drainage Areas	Run-off Calculation Procedure
Up to 0.8 km^2	Rational Method
Up to 2 km^2	Santa Barbara Method
Up to 52 km^2	SCS Method
Any drainage area	HEC-1

Erosion from soil surfaces is estimated using the Universal Soil Loss Equation, and sediment storage is included in sizing retention basins to be used during construction. A retention basin in operation is shown in Figure 2. Where necessary a water treatment plant may be provided to remove contaminants before discharge of run-off and dewatering water collected during construction. Such a plant is also shown in the photograph.

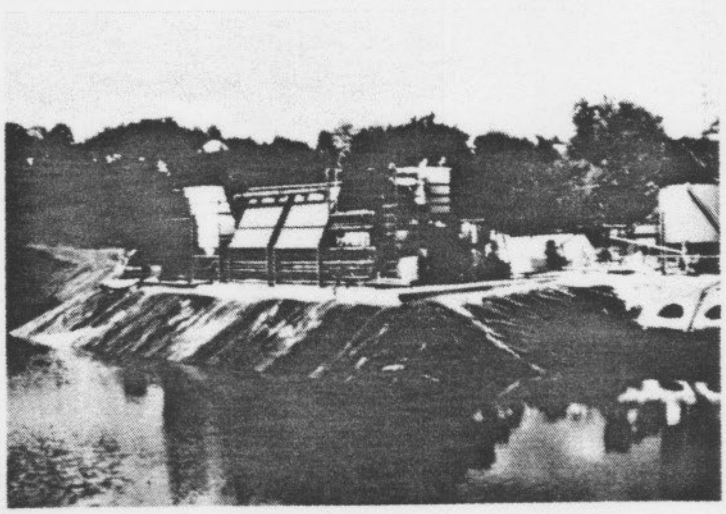


Figure 2 - Water Treatment Plant and Sedimentation Pond

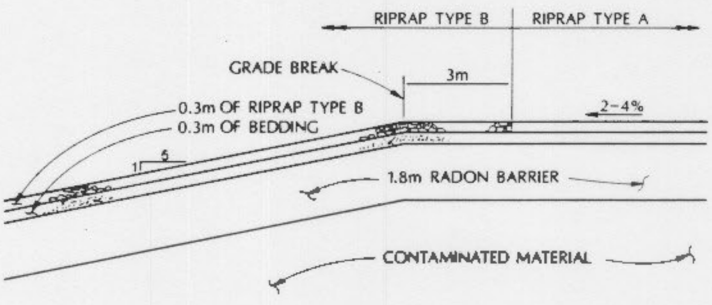
Erosion protection is a critical element in providing assurance that tailings will remain isolated from the environment. Rock riprap is the only material considered to have the proven longevity required for the specified design life. Riprap sizes to resist the shear stresses developed by run-off from the design storm are determined as follows:

Erosion Protection for:	Design Method
1. Embankment slopes flatter than 10% and all ditches.	Safety Factors Method (Stevens, et. al., 1976)
2. Embankment slopes steeper than 10%.	Stephenson's Method (Stephenson, 1979)

This assignment of different design methods for different embankment slopes is based on the results of recent tests at Colorado State University (unpublished).

The run-off flow rate governing riprap size for a given slope or ditch is a function of the time of concentration for flow to the toe of the slope or to the downstream end of the ditch. This time in turn is a function of flow velocity which is a function of riprap size. Thus design is an interactive process, greatly facilitated by the use of computer codes.

The design methods give the mean rock size required to resist the peak flow from the design storm. Empirical relationships are then used to set gradation limits and thickness for the riprap layer and to design protective bedding, if required, between the riprap and the radon barrier. Figure 3 shows an example design.



CROSS-SECTION OF EXAMPLE COVER
Figure 3

Radon Barrier Design

The radon barrier serves two proposes:

1. To limit the average radon exhalation to 20 pCi/m^2/sec. or less.

2. To limit infiltration of precipitation to the extent necessary to cause effluent from the site to meet water quality standards.

The barrier is generally designed to meet Purpose 1, and then checked for satisfaction of Purpose 2. Special procedures may be necessary to adjust the design to meet Purpose 2.

The basic approach to design is to determine the thickness of the barrier using the RAECOM model (Rogers, et.al., 1984). The following parameters are needed as input to this model:

1. The projected radium content and emanating fraction of the tailings.

2. The radon diffusion coefficient of the barrier material. (Available local materials, preferable clayey materials, are tested to determine this parameter.)

Once the thickness of the radon barrier has been determined the average annual infiltration can be estimated. The distribution of rainfall, evaporation and evapotranspiration throughout the year may be taken into account. The concentration of contaminants leached from the tailings by the estimated infiltration is computed and used to predict contaminant migration to adjacent aquifers or surface water sources. The resulting concentrations are compared to applicable water quality standards (state or federal) to assess the need for further design provisions. For example bentonite could be added to the radon barrier material to reduce hydraulic conductivity, resulting in a lower rate of infiltration.

During the initial phase of construction the radon barrier materials are sampled and tested for the radon diffusion coefficient. The projected radium content of at least the upper three meters of tailings is also determined. The final thickness of radon barrier is then adjusted, as appropriate, to meet the radon exhalation criteria.

Settlement, Stability and Liquefaction Analyses

Settlement analyses are accomplished to assess differential settlements, which could cause:

1. Cracking of the radon barrier. Design adjustments may be necessary to meet radon flux limits.

2. Flow concentrations or ponding. Design adjustments may be required to maintain sheet flow and drainage as assumed in erosion protection design and infiltration analysis.

Conventional soil mechanics procedures are used. The load applied is the weight of material placed on site. The methods are:

1. Elastic theory for sands or non-saturated clays.

2. Consolidation theory for clays.

3. Secondary compression approach for post-consolidation settlement.

4. Empirical methods for non-elastic compression of sands and non-saturated clays.

The potential for cracking is assessed by comparing the tensile strains computed for the estimated differential settlements to the strains required to cause cracking. Design adjustments may include: 1) pre-loading the compressible materials, possibly with sand drains; 2) relocating the upper portion of the compressible material to reduce its thickness or to eliminate abrupt changes in thickness.

Stability analyses are implemented to judge the potential for:

1. Disruption of the radon barrier or erosion protection by sliding of a slope due to static or dynamic (earthquake) loading.

2. Dislocation of tailings by slope failure.

Bishop's Modified Method of Analysis (Bishop, 1955) and the Sliding Wedge Method (Lambe and Whitman, 1959) are used. The cases analyzed, the types of shear strength information required and the minimum factor of safety required for each case are taken from experience with earth dams, and are listed in Table 2.

TABLE 2: GUIDELINES FOR SEEPAGE AND LOADING CONDITIONS, MINIMUM FACTORS OF SAFETY, AND TYPES OF SHEAR TESTS FOR STABILITY ANALYSES

Case No.	Design Condition	Load Condition	Type of Shear Strength Data Required	Minimum Factor Safety Required
I	End of Construction	Static (without -EQ forces)	UU or Q	1.30
		Pseudo-static (with EQ. forces)	Same as above	
II	Long-Term with no water or Minimum Storage Pool	Static (without EQ. forces)	CD or S	1.1-1.I5
			or CU or R with pp measurements	1.5
		Pseudo-static (with EQ. forces)	Same as above	1.1-1.15
III	Steady Seepage with Maximum Storage Pool (Long-Term)	Static (without EQ. forces)	CD or S or CU or $\bar{R}$ with pp measurements	1.5
		Pseudo-static (with EQ) forces)	Same as above	1.1-1.15
IV	Sudden Drawdown from Maximum Storage Pool	Static (without EQ. forces)	CU or R	1.25-1.50
V	Partial Pool with Steady Seepage	Static (without EQ. forces)	CD or S or CU or R with pp measurements	1.5
		Pseudo-static (with EQ. forces)	Same as above	1.1-1.15

Liquefaction analyses are conducted where saturated cohesionless materials may be subjected to vibratory loading or shock (usually caused by an earthquake). The increase in pore pressure caused by liquefaction will have two effects:

1. A decrease in shear strength, reducing the factor of safety against slope failure.

2. Increased settlement, as water flows from the material to relieve the increased pore pressures.

One or more of the following methods of analysis are used:

1. Seed and Idriss Simplified Method (Seed and Idriss, 1971).

2. Chinese Empirical Method (Taiping, et. al., 1984).

3. Evaluation of Relative Density or Standard Blow Count.

If design adjustments are necessary (factor of safety against liquefaction less than 1) dynamic consolidation as well as the measures to reduce settlement listed above will be considered.

NUCLEAR REGULATORY COMMISSION STANDARD REVIEW PLAN

The remedial action plan prepared by the DOE is submitted to NRC for concurrence. The basic requirements for NRC concurrence are:

- Reasonable assurance of compliance with EPA standards.

- Measures required to follow EPA guidance to protect against existIng and further ground-water contamination as required by 40 CFR 192.20(a)(2).

In order to guide NRC reviewers, the NRC has compiled the NRC Standard Review Plan (NRC-SRP). The primary purpose of the document is to help assure that reviews are performed and documented in a thorough, focused, efficient, and consistent manner. A second purpose is to improve understanding of the NRC UMTRA Project review process. Each chapter of the NRC-SRP addresses the matters that are reviewed, the basic information needed for review, how the review is accomplished, and the conclusions that are sought.

The NRC-SRP does not provide detailed acceptance criteria or step-by-step procedures to be used, except where the NRC considers there is a need for an elaboration of its position.

The NRC-SRP is divided into the same four main sections as the Technical Approach Document. These are: Surface Water Hydrology and Erosion Protection; Geotechnical Stability; Radon Attenuation; and Water Resource Protection. The following is a brief discussion of some of the key requirements or aspects of the NRC-SRP that influence the design of remedial works.

Design Floods (Surface Water Hydrology and Erosion Protection)

The NRC-SRP requires the use of the Probable Maximum Precipitation and the Probable Maximum Flood for design. If it is demonstrated to the NRC that design for such events is "clearly excessive," the NRC reviews the contention in accordance with the procedure given in Table 3.

Radon Barrier Moisture Content (Radon Attenuation)

The NRC-SRP considers that the moisture content chosen for the radon barrier is acceptable if it represents a long-term moisture content that conservatively bounds the lower moisture retention capacity of the soil. The value should represent the lowest moisture content that the soil can be expected to experience for any one-year period during the long-term design life of the project. NRC considers the 15-bar moisture content to be this value. The DOE considers that the lowest average 30-year moisture content is in accordance with the EPA standards and that a moisture content higher than the 15-bar value corresponds to the average 30-year moisture content. However the 15-bar value is currently used for design.

The NRC will also accept the value predicted by the formula given in Rawl and Brakensiek (1982); this formula relates moisture content to soil type and soil suction pressure.

Water Resource Protection

The NRC-SRP requires detailed assessment of the risks associated with the use of water in the vicinity of UMTRA Project sites. The level of detail may vary from site to site depending on environmental concerns, site complexity, or the conservativeness of the assumptions made in the analysis.

In general the NRC accepts that risk assessments, health impacts modelling, and environmental assessments are not required when contamination levels cause the water quality to be below drinking water standards. Just because the water is not currently being used does not, however, eliminate the need for an assessment of health impacts that would occur if the ground water were used.

General

In general there is substantial agreement between the NRC-SRP and the Technical Approach Document. Where differences exist in approach or methods or criteria, these differences are worked out by detailed discussion between the technical staff of the relevant organizations. To date, all remedial action plans submitted by DOE have been concurred in by the NRC.

TABLE 3: METHOD TO REVIEW APPLICATION FOR NON-PMP DESIGNS

Step 1 Review DOE's procedures which identify the least costly of several remedial action designs and design configurations which could be implemented to withstand the PMP/PMF.

Step 2 Review DOE's procedures which identify the least costly of several rock sources that could be used with the design identified in Step 1.

Step 3 Review DOE's procedures which determine the erosion protection cosrs associated with the least costly design that will be capable of withstanding the PMP/PMF. DOE should break down costs by unit cost and total cost in the following categories:

- o Erosion protection for top of pile.
- o Erosion protection for sides of pile.
- o Erosion protection for aprons at the toes of slopes.
- o Erosion protection for drainage and diversion channels.
- o Erosion protection for banks of large adjacent streams.
- o Earthwork and miscellaneous features needed specifically for erosion protection.

DOE should also identify the costs associated with moving to the least expensive alternative site, with cost breakdowns included, as above.

Step 4 Review DOE's procedures which identify rock sizes that are readily available in the site area and could be used at a cost savings. Several sources should be identified by DOE and compared for cost, rock size availability, and durability.

Step 5 Review DOE's procedures which determine the magnitude of the flood (and the percentage of the PMP/PMF) that a less expensive rock source and design will withstand. DOE should assume designs and computational methods similar to the designs and computational methods employed in Step 1, and should assume that the less costly erosion protection design will be used.

A plot should be developed to graphically show the relationship of erosion protection costs vs. the percentage of the PMP/PMF that can be withstood.

If a well-defined "break point" exists in the graph, where the costs increase dramatically as a result of increase in the flood discharge, this "break point" may provide a reasonable basis for determining an appropriate flood magnitude for design.

TABLE 3: METHOD TO REVIEW APPLICATION FOR NON-PMP DESIGNS

(CONCLUDED)

Step 6 Review DOE procedures which fine tune the design, as necessary, and determine the erosion protection costs associated with the less expensive design in each of the categories identified in Step 3.

Step 7 Review DOE's comparison of the total costs of the project and the costs of the erosion protection. In order to determine if the costs of providing erosion protection to withstand the PMP/PMF are clearly excessive, the following minimum criteria are suggested:

- o The costs of erosion protection for the PMP/PMF design significantly exceeds the average cost for other similar UMTRA Project sites.
- o The costs of erosion protection for the PMP/PMF design, as a percentage of the total project cost, is significantly greater than the average cost for other similar UMTRA Project sites.
- o A significant savings results from using the less expensive design.

Step 8 Review DOE's documentation which demonstrates that EPA standards are met by the reduced design. Information and analyses which will be reviewed include the following:

- o Drawings and supporting hydraulic calculations for each design analyzed.
- o Backup calculations which provide the bases for the cost estimates identified for each design flood.
- o Supporting hydraulic calculations for determination of PMP/PMF and selected design flood.
- o Supporting logic and bases which document that the design selected meets EPA longevity criteria.

CONCLUSION

This paper discussed the four main documents that govern the process of design, of concurrence by regulatory bodies, and the construction of remedial works at inactive uranium piles in the U.S. The paper described the general technical approaches,

REFERENCES

BISHOP, A. W., 1955, "The Use of the Slip Circle in the Stability Analysis of Earth Slopes," Geotechnique, Vol. 5, pages 7-17.

BONILLA M. G. Bonilla, R. K. Mark, and J. J. Lienkaemper, 1984. "Statistical Relations Among Earthquake Magnitude, Surface Rupture Length, and Surface Fault Displacement," Bulletin of the Seismological Society of America, Vol. 74, pp. 2379-2411.

BRAKENSIEK D. L., W. J. Rawls, and B. Soni, 1982 "Infiltration Parameter Values for Transient Soil Condition," American Society of Agricultural Engineers, St. Joseph, Michigan.

CAMPBELL, K. W., 1982. "A Preliminary Methodology for the Regional Zonation of Peak Ground Acceleration," in Proceedings of the Third International Earthquake Microzonation Conference, Seattle, Washington, Vol. 1, pp. 365-376.

DOE (U.S. Department of Energy), 1986, Technical Approach Document, UMTRA-DOE/AL-050425.0000, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

GUPTA, S. C., and W. E. Larson, 1979. "Estimating Soil Water Retention Characteristics from Particle Size Distribution, Organic Matter Percent and Bulk Density," U.S. Department of Agriculture, Soil and Water Management Unit, University of Minnesota, St. Paul, Minnesota.

LAMBE, T. W. and R. V. Whitman, 1969, Soil Mechanics, John Wiley & Sons, Inc., New York, New York.

MORRISON-KNUDSEN ENGINEERS, INC., 1986, "Uranium Mill Tailings Remedial Action (UMTRA) Design Procedures Manual," Morrison-Knudsen Engineers, Inc., San Francisco, California, May.

RAWLS, W. J., D. L. Brakensiek, and K. E. Saxton, 1982. "Estimation of Soil Water Properties," American Society of Agricultural Engineers, St. Joseph, Michigan.

RAWLS, W. J. and D. L. Brakensiek, 1982. "Estimating Soil Water Retention from Soil Properties," Journal of the Irrigation and Drainage Division, ASCE, Vol. 1 108, No. IR2, June, 1982. Radon Attenuation Handbook for Uranium Mill Tailings Cover Design, U.S. Nuclear Regulatory Commission, NUREG/CR-3533.

SEED, M. B. and I. M. Iriss, 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential," Journal of the Soil Mechanics and

REFERENCES

SLEMMONS et al. D. B., P. O'Malley, R. A. Whitney, D. H. Chung, and D. L. Bernreuter), 1982. "Assessment of Active Faults from Maximum Credible Earthquakes of the Southern California-Northern Baja Region," University of California, Lawrence Livermore National Laboratory, Livermore, California, Publication No. UCID 19125, 48 p.

STEPHENSON, David, 1979. Rock Fill in Hydraulic Engineering, Elsevier Scientific Publishing Company, New York, New York.

STEVENS, M. A. D. B. Simons, and G. L. Lewis, 1976. "Safety Factors for Riprap Protection," in American Society of Civil Engineers, Journal of Hydraulic Engineering.

TAIPING, Q., W. C. Chenchun, W. Lunian, and L. Moishan, 1984, "Liquefaction Risk Evaluation During Earthquakes, Proc., International Conference on Case Histories in Geotechnical Engineering, St. Louis, Vol. 1, p. 445-454.