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PERFORMANCE ASSESSMENT OF
SELECT COVERS AND DISPOSAL CELL
COMPLIANCE WITH EPA
GROUNDWATER STANDARDS

JUNE 1989

MASTER

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1.0 INTRODUCTION

This document describes the technical approach to the assessment of the performance of a full component topslope cover, three sideslope covers, and hence the way in which a Uranium Mill Tailings Remedial Action (UMTRA) Project disposal cell complies with the U.S. Environmental Protection Agency (EPA) groundwater protection standards.

2.0 BACKGROUND

2.1 DESCRIPTION OF FULL COMPONENT TOPSLOPE COVER

The report "Remedial Action Planning and Disposal Cell Design" (DOE, 1989a) describes in detail the various components of the full component cover as proposed for UMTRA Project disposal cells. In brief, a full component cover incorporates the following components (from the top of the cell down):

- o Gravel mulch to control erosion (optional).
- o Soil to support vegetation.
- o Vegetation to control erosion and enhance evapotranspiration.
- o Filter to prevent soil piping.
- o Gravel to prevent biointrusion.
- o Drain or bedding layer to shed water and protect underlying layers.
- o CLAYMAX^R to impede infiltration.
- o Compacted silt and clay to control radon emissions and impede infiltration.

The thickness and material specifications of the various layers described above are selected on a site-specific basis to respond to local conditions and use available construction materials.

2.2 PREVIOUS DESCRIPTIONS OF COVER PERFORMANCE

The report on remedial action planning and disposal cell design describes the performance of a full component cover. The revised UMTRA Project Technical Approach Document (TAD) (DOE, 1989b) details the technical approach to assessing the performance of a full component cover and the way in which the disposal cell complies with the EPA groundwater protection standards. The document "Water Resource Protection Strategy for Tailings Disposal at Cheney Reservoir Disposal Site" (DOE, 1988) provides a comprehensive description of the design and performance assessment of most of the components of a full component cover for the proposed disposal site at Cheney, Colorado.

The following are some quotes, from the documents referenced above, that briefly describe past approaches to the assessment of infiltration or water flux through a full component cover:

- o Infiltration through the full component cover is controlled by four mechanisms: (a) evapotranspiration of precipitation by the plants and the soil; (b) the capillary barrier effect of the filtered or choked rock beneath the soil, which impedes drainage from the soil and holds the water until it is evapotranspired; (c) lateral shedding of any seepage that percolates through the soil through the permeable drain and down the inclined slopes of the cell; and (d) impeded flow through the low permeability infiltration barrier and the radon barrier (DOE, 1988).

- o The vegetation: at the Cheney site evapotranspiration will draw water from the soil and remove it from the cover. This limits the percentage of precipitation available to seep to the underlying drain. The soil, which is thick, will act as a reservoir to hold up to the 100-year recurrence interval precipitation infiltration (DOE, 1988).
- o CLAYMAX: an infiltration barrier consisting of a bentonite mat has been included in the cover design to provide a performance standard (steady-state) seepage rate of 2×10^{-9} cm/s (centimeters per second) (DOE, 1989b).
- o The radon barrier: placed at a saturated hydraulic conductivity of 1×10^{-7} cm/s, this layer will probably be unsaturated because of limited influx of water from the overlying vegetation, soil, and geosynthetic. Because the barrier will most probably be (operate) partially saturated, its unsaturated hydraulic conductivity (the flux) will be less than 1×10^{-8} cm/s, and likely no more than 1×10^{-9} cm/s (DOE, 1989a).
- o The cover (i.e., a full component cover) will limit the infiltration to tailings to 1×10^{-8} to 1×10^{-9} cm/s (DOE, 1989a).

The U.S. Nuclear Regulatory Commission (NRC) in Kape and Widmayer (1989) state with regard to geosynthetics such as CLAYMAX^R:

- o Because of the important advantages offered by the use of geosynthetics at radioactive waste disposal facilities, the use of these materials is encouraged.
- o To compensate for the uncertainties associated with the long-term performance of geosynthetics, and to provide the level of confidence that is required by federal regulations, the use of a geosynthetic alone is not recommended. However, the use of geosynthetics to complement and improve the performance of natural soil and rocks or other proven construction materials is recommended by the staff.

This latter statement by the NRC parallels the DOE approach, which is stated thus:

"In reality there is considerable interaction of the various components (of the full component cover). It has been said that the various components, properly selected, form a functional synergistic entity" (DOE, 1989a).

2.3 ASSESSMENT OF COVER PERFORMANCE OTHER THAN INFILTRATION

Assessment of the erosional resistance, longevity, radon impedance, vegetation support capacity, and so on of the full component topslope cover is described in detail in the TAD, and is not discussed here.

3.0 FULL COMPONENT TOPSLOPE COVER INFILTRATION PERFORMANCE ASSESSMENT

3.1 SENSITIVITY APPROACH

The NRC has requested that an assessment of the performance of a disposal cell consider a range of likely inflow and seepage scenarios; they seek a sensitivity analysis of the potential for contaminant flux from the disposal cell and the potential for compliance with the EPA groundwater protection standards.

In the preamble to the draft final EPA groundwater protection standards, the EPA states:

"The EPA has decided not to delete the ACL [alternate concentration limit] provision because it is clearly needed, if for no other reason than to deal with the possibility of unavoidable minor projected seepage over the extremely long-term design life (up to 1,000 years) of the disposal required by these standards...

It is clear for controlled minor seepage next to disposal areas and when public use is not possible, that ACLs will usually be appropriate in such situations."

It simply is not possible to state definitively a single value for the flux through a full component cover. The DOE considers that inherent uncertainties in the individual performance of the separate components of the full component cover, and uncertainties regarding the interaction or synergistic effects of the various cover components, make it necessary to consider a range of possible infiltration fluxes through a full component cover.

For this reason and because of the NRC request for sensitivity analyses, the proposed technical approach to full component cover performance evaluation and disposal cell groundwater compliance discussed in this report incorporates the philosophy of uncertainty and sensitivity analyses. As noted by the EPA, if such an approach leads to a calculated exceedance of maximum concentration limits then "ACLs will usually be appropriate...."

3.2 THEORETICAL APPROACH

The actual flux through a full component cover is likely to vary from about 1×10^{-8} cm/s to less than 1×10^{-9} cm/s. The DOE considers that it is not possible to establish the actual operative flux for a specific case. Variations in materials, the performance of the individual cover components, the configuration of the cover geometry and the interaction of site climate and cover response make it theoretically impossible to establish a single point value for the flux. In reality there is some (as yet undetermined) probability distribution curve for the flux through a full component topslope cover.

Neither the DOE nor anyone else have technical data to support a proposed probability distribution curve of flux through a full component topslope cover. It is probably not possible to establish analytically or by testing the range and distribution of flux through a full component topslope cover; it is also probably not necessary as long as the assessment of the performance of a disposal cell considers the range of possibilities and establishes a suitable groundwater compliance strategy for reasonable water fluxes.

3.3 LIKELY OPERATIVE WATER FLUX

The DOE proposes that the "likely operative water flux" through a full component topslope cover will be 2×10^{-9} cm/s. As the term for this flux implies, it is the most likely value for the seepage rate through the full component cover. There is a small probability that the actual flux will be less, and there is a probability that the flux will be more. The likely operative water flux is proposed as 2×10^{-9} cm/s because this is the test hydraulic conductivity of the lowest permeability element in the cover, i.e., the CLAYMAX. (See DOE, 1989b for test data.) The probability for lesser fluxes arises because of the limited chance that precipitation infiltration and/or snowmelt will actually seep through the overlying soil before it is evapotranspired, and thus increase the hydraulic gradient across the bentonite mat to a value greater than unity. Assessment of the way in which a disposal cell complies with the EPA groundwater protection standards will consider the range of possible fluxes.

3.4 CONSERVATIVE AVERAGE WATER FLUX

The DOE proposes that 5×10^{-9} cm/s be used as a conservative average water flux through the full component cover. It is at least conceivable that the actual flux through the cover is equally likely to be greater than or less than this flux. It is also realized that actual cover flux will vary above and below the average depending on seasonal variability.

This value is proposed because it represents a rounded value of overall flux through a CLAYMAX layer. Approximately five percent of the CLAYMAX layer is considered to be inoperative, and is underlain by and interacts with a radon barrier with a hydraulic conductivity of 1×10^{-8} cm/s, a reasonable value for a partially saturated soil at the base of a full component topslope cover.

3.4 UPPER BOUND WATER FLUX

The DOE proposes that the upper bound value of the water flux through a full component topslope cover be 1×10^{-8} cm/s. While it is conceivable that the actual flux could be greater, the DOE considers the probability very small.

Furthermore, if the DOE is forced by regulatory concern to base its disposal cell compliance strategy on a flux of 1×10^{-8} cm/s or greater, there is no logic in including the CLAYMAX layer in the cover. This is because it is undoubtedly possible to place compacted soil to saturated hydraulic conductivities of 1×10^{-8} cm/s. The DOE believes such an approach would be inconsistent with the NRC attitude of combining natural materials with geosynthetics for the added benefits they provide.

4.0 BACKGROUND FOR THREE SIDESLOPE COVERS

4.1 DESCRIPTION OF THREE SIDESLOPE COVERS

4.1.1 Standard

The standard sideslope cover incorporates the following components (from the surface down):

- o Small or large diameter rock to prevent erosion.
- o Filter and bedding to shed water laterally off the pile sideslopes and to provide a bedding layer for the overlying rock.
- o Compacted silt and clay to control radon emissions and impede infiltration. (This layer is called the infiltration/radon barrier).

The thickness and material specifications of the various layers are selected on a site-specific basis.

4.1.2 Double drain

The double drain sideslope cover incorporates the following components (from the surface down):

- o Large or small diameter rock.
- o Filter and bedding.
- o Random (or select) fill layer to protect the infiltration/radon barrier from freezing.
- o Sand drain to shed water that seeps from the random fill layer and to prevent the buildup of an hydraulic head over the infiltration/radon barrier.
- o Infiltration/radon barrier.

The thickness and material specifications of the various layers are selected on a site-specific basis.

4.1.3 Clean fill dike

The clean fill dike sideslope consists of a perimeter dike constructed of compacted, low permeability material obtained from either an off-site borrow source or from excavation of the disposal cell before placement of tailings.

The outer slope of the dike could be placed at a very flat gradient and covered with soil and vegetation, or placed at a slope as steep as three horizontal to one vertical and covered with erosion resistant rock riprap or soil and vegetation. The materials for the various components are selected on a site-specific basis.

4.2 Previous descriptions of cover performances

4.2.1 Standard

Two documents describe the performance and technical approach to assessing the performance of the standard cover (1) the report on remedial action planning and disposal cell design (DOE, 1989a); and 2) the revised TAD (DOE, 1989b).

Information in the documents indicate that infiltration through the standard sideslope cover is controlled by two mechanisms:

- o Lateral shedding of infiltration through the permeable drain and down the steep, inclined slopes of the cell; and
- o Impeded flow through the low permeability infiltration/radon barrier.

The following are some paraphrased and elaborated statements from the documents referenced above, that briefly describe past approaches to the assessment of infiltration or water flux through the standard sideslope cover:

- o The radon barrier: placed at an operative saturated hydraulic conductivity of 1×10^{-7} cm/s or less. This layer will probably be unsaturated, particularly if: 1) a full component cover is used for the topslope - the vegetated soil cover will limit the amount of surface runoff (as well as infiltration through the topslope drain layer) that flows over the crest onto the sideslopes; and 2) the site is in an arid region where the annual precipitation is nine inches or less - the operative unsaturated hydraulic conductivity (flux) of the barrier will be less than 1×10^{-9} cm/s (DOE, 1989a).
- o Bentonite-amended soils: soils with up to 30 percent bentonite by volume placed at an operative saturated hydraulic conductivity of 1×10^{-8} cm/s or less. The actual hydraulic conductivity achieved with bentonite-amended soil is material specific and would have to be determined on a site-specific basis (DOE, 1989a).

4.2.2 Double drain

Previous statements about double drain covers in (DOE, 1989a) are:

- o The zone of random soil will serve as a growth medium for deep-rooting plants.
- o It is unlikely that the infiltration barrier of this cover will be unsaturated because the random soil will act as a sponge continually dripping water into the underlying drain; therefore in calculating water flux through the cover, it will be necessary to assume saturated conditions in the infiltration barrier.
- o The saturated hydraulic conductivity of the soil of the infiltration barrier governs infiltration.

4.2.3 Clean fill dike

Previous statements about clean fill dike sideslopes in (DOE, 1989a) are:

- o (With a clean fill dike) there is no potential for seepage through contaminated material underlying the sideslopes.
- o (The clean fill dike design) may facilitate groundwater compliance with EPA groundwater protection standards at sites where it is necessary to significantly or severely limit the quantity of contaminated seepage from the cell.
- o Clean fill dikes are a valuable option in achieving maximum concentration limits (MCLs).
- o There is no need to decide if flow through the (clean fill) dike will be saturated or partially saturated because there are no tailings beneath the dikes and no possibility for contamination of seepage.
- o There is no need to be concerned about freeze and thaw effects on the compacted soil.
- o Vegetation may establish and the roots grow deep, without concern for biointrusion to the tailings.

4.3 ASSESSMENTS OF COVER PERFORMANCES OTHER THAN INFILTRATION

Assessment of the erosional resistance, longevity, radon impedance, vegetation support capacity (particularly for the clean fill dike design with sideslope vegetation), and so on, of the three sideslope covers is described in detail in the TAD (DOE, 1989b), and is not discussed here.

5.0 INFILTRATION ASSESSMENTS FOR THREE SIDESLOPE COVERS

5.1 SENSITIVITY APPROACH

The NRC has requested that an assessment of the performances of a disposal cell consider a range of likely inflow and seepage scenarios; they seek a sensitivity analysis of the potential for contaminant flux from the disposal cell and the impact of such seepage from groundwater.

As with the full component topslope cover, it is not possible to state definitively single values for fluxes through the three different sideslope covers. The DOE considers that inherent uncertainties in the individual performance of the separate components of the sideslope covers make it necessary to consider a range of possible infiltration fluxes through the sideslope covers.

For this reason and because of the NRC request for sensitivity analyses, the proposed technical approach to sideslope cover performance evaluation and disposal cell groundwater compliance discussed in this report incorporates the philosophy of uncertainty and sensitivity analyses.

5.2 THEORETICAL APPROACH

5.2.1 Standard and double drain

The actual fluxes through the standard and double drain sideslope covers are based on the permeability of the lowest permeability layer (i.e. infiltration/radon barrier) and are likely to vary from about 1×10^{-7} cm/s to 1×10^{-9} cm/s. As with the full component topslope cover, the DOE considers that it is not possible to establish actual operative fluxes for a specific cases, for the same reasons mentioned in Section 3.2. There are some (as yet undetermined) probability distribution curves for the fluxes through the two sideslope covers.

The DOE has no technical data to support proposed probability distribution curves of flux through the standard and double drain sideslope covers. It is probably not possible to establish analytically or by testing the range and distribution of fluxes through these covers. It is also probably not necessary as long as the assessment of their performance considers the range of possibilities and establishes suitable groundwater compliance strategies for reasonable water fluxes.

5.2.2 Clean fill dike

The actual flux through the clean fill dike sideslope cover is dependent upon the soil properties of the clean fill material and the degree of compaction that is required for stability. However, because seepage from the dike will not be contaminated and will not affect compliance with the groundwater standards, the flux through the dike is not of significance in groundwater compliance assessments and thus, will not be discussed further in the subsequent sections.

5.3 LIKELY OPERATIVE WATER FLUX

5.3.1 Standard

The DOE proposes that the "likely operative water flux" through the standard sideslope cover will be designated on a site-specific basis. The designated value will be based on the unsaturated hydraulic conductivity of the lowest permeability layer at a conservative anticipated operative moisture content (i.e. infiltration/radon barrier). There is a probability that the actual flux will be higher and a probability that it will be lower than the selected design unsaturated hydraulic conductivity. The variability will depend upon the properties of the barrier material and the site-specific climatic conditions.

5.3.2 Double drain

The DOE proposes that the "likely operative water flux" through the double drain sideslope cover will be designated on a site-specific basis. The designated value will be based on the unsaturated hydraulic conductivity of the lowest permeability layer at a conservative operative moisture content (i.e. infiltration/radon barrier). There is a probability that the actual flux will be higher and a probability that it will be lower than the selected design unsaturated hydraulic conductivity. The variability will depend upon the properties of the barrier material and the site-specific climatic conditions.

5.4 CONSERVATIVE AVERAGE WATER FLUX

5.4.1 Standard

The DOE proposes that the conservative average water flux through the standard sideslope cover be equivalent to the saturated hydraulic conductivity of the lowest permeability layer. The actual value will be obtained from test data and will represent the harmonic mean saturated hydraulic conductivity. In general, the conservative average water flux will vary from 10^{-7} to 10^{-8} cm/s.

5.4.2 Double drain

The conservative average water flux for the double drain sideslope cover will be the harmonic mean saturated hydraulic permeability based on actual test data for the saturated hydraulic conductivity of the lowest permeability layer.

5.5 UPPER BOUND WATER FLUX

5.5.1 Standard

The DOE proposes that in the absence of specific laboratory and field test data to confirm a lower value, the upper bound value of the water flux through a standard sideslope cover be 1×10^{-7} cm/s. This value is considered to be a reasonable value that is relatively easily achieved in the field with normal soils. It is conceivable that the actual flux could be greater; however, the DOE considers the probability is very small.

5.5.2 Double drain

The DOE proposes that in the absence of specific laboratory and field test data to confirm a lower value, the upper bound value of the water flux through a double drain sideslope cover be 1×10^{-7} cm/s. It is conceivable that the actual flux could be greater; however, the DOE considers the probability is very small.

6.0 DISPOSAL CELL GROUNDWATER COMPLIANCE

6.1 MAXIMUM CONCENTRATION LIMITS/BACKGROUND CONCENTRATIONS (MCLs/BC)

The DOE proposes to adopt MCLs/BC as the disposal cell groundwater compliance strategy if both the likely operative flux and the conservative average flux result in a prediction of no exceedance of MCLs/BC at the facility's point of compliance.

If the upper bound flux could result in an exceedance of MCLs/BC but the likely and conservative average flux would not, the DOE proposes to note that it will monitor for potential exceedances and apply alternate concentration limits (ACLs) as a corrective action should such exceedances be detected or projected. This is consistent with EPA's guidance as previously discussed.

If the likely operative flux would result in MCLs/BC or less at the point of compliance, but the conservative average and the upper bound flux indicate potential exceedances of MCLs/BC, then the DOE will proceed as follows:

- o The operative compliance strategy will be MCLs/BC.
- o The DOE will note that ACLs constitute a potential corrective action if an exceedance is detected or projected.
- o The DOE will establish with appropriate calculations and evaluations that ACLs are potentially appropriate as a corrective action or alternative compliance strategy. This might, for example involve a demonstration of no significant potential health or environmental impact in the event of an exceedance of MCLs and that the design reduces seepage to levels as low as reasonably achievable (ALARA).

The technical approaches proposed in this section are considered to be fully consistent with the EPA proposal that ACLs are appropriate to deal with the possibility of unavoidable minor seepage over a design life of 1,000 years.

6.2 ALTERNATE CONCENTRATION LIMITS (ACLs)

The DOE will compile an ACL application if the likely operative flux indicates a potential exceedance of MCLs at the facility's point of compliance.

In establishing that the design meets the ALARA concept, the DOE will base its assessment on the fact that covers that reduce flux to a greater extent than the full component topslope cover and/or the clean fill dike sideslope cover are probably not possible within the context of the EPA requirement for longevity. Numerous special studies completed by the DOE substantiate this contention.

6.3 SUPPLEMENTAL STANDARDS (SS)

If the disposal cell groundwater compliance strategy is to apply for supplemental standards, the DOE may choose to construct a full component topslope cover and/or any one of the sideslope covers. The decision will be based on the requirements of 40 CFR 192.22(a), which states:

"When one or more of the criteria (for SS) applies, the implementing agencies shall select and perform remedial actions that come as close to meeting the otherwise applicable standards as is reasonable under the circumstances."

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