UNITED STATES
NUCLEAR REGULATORY COMMISSION

January 31, 2018

MEMORANDUM TO: Maria Arribas-Colon, Acting Chief
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Office of Nuclear Materials Safety and Safeguards

THRU: Christepher A. McKenney, Chief
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SUBJECT: TECHNICAL REVIEW: HYDRAULIC PERFORMANCE AND EROSION CONTROL OF THE PLANNED SALTSTONE DISPOSAL FACILITY CLOSURE CAP AND ADJACENT AREA (DOCKET NO. PROJ0734)

The U.S. Nuclear Regulatory Commission (NRC) staff has performed a technical review of the hydraulic performance and erosion control of the planned Saltstone Disposal Facility (SDF) closure cap and adjacent area as part of the NRC monitoring of the U.S. Department of Energy (DOE) disposal actions at the Savannah River Site (SRS) SDF.

The NRC review was performed in accordance with monitoring activities described in the NRC 2013 SDF Monitoring Plan (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13100A113). This NRC Technical Review Report (TRR) is related to Monitoring Area (MA) 2 (Infiltration and Erosion Control) and MA 10 (Performance Assessment Model Revisions) in that monitoring plan. Within those two MAs, this TRR addresses Monitoring Factor (MF) 2.01 (Hydraulic Performance of Closure Cap), MF 2.02 (Erosion Protection), and MF 10.02 (Defensibility of Conceptual Models).

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This TRR recommends (1) increasing the priority of MF 2.01 from low priority to medium priority, (2) modifying MF 2.02 to clarify that areas adjacent to the future SDF closure cap will be under the NRC monitoring activities at the SDF, and (3) adding a new MF 10.14 (Scenario Development and Defensibility) under MA 10 (Performance Assessment Model Revisions).

The performance of the closure cap affects the overall performance of the SDF because the closure cap is designed to: (1) provide physical stabilization, (2) limit infiltration, and (3) act as an intruder deterrent. MF 2.01 encompasses those technical aspects relevant to limiting infiltration. Due to the relative importance of the rate of infiltrating water through the wasteform, and due to the concerns about the hydraulic performance of, and minimizing infiltration through, the closure cap as discussed and presented in this TRR, the NRC staff recommends increasing the priority of MF 2.01 from low priority to medium priority.

MF 2.02 is a low-priority monitoring factor and encompasses those technical aspects pertaining to controlling erosion. The status of MF 2.02 remains unchanged; however, this report recommends changing the title and description of MF 2.02. This report discusses the future SDF closure cap and the engineered cover layers below the closure cap that will be built on the current Z Area and discusses the adjoining land that will act as a foundation for the engineered surface barrier. The previous description of MF 2.02 has focused exclusively on the upper part of the engineered surface cover (i.e., the closure cap). However, due to the importance of controlling erosion in the area surrounding the SDF, the staff recommends clarifying that areas adjacent to the future closure cap are monitored as part of the monitoring activities. Consequently, the staff recommends revising the title of MF 2.02 based on this TRR to read as follows: Erosion Control of the SDF Engineered Surface Cover and Adjacent Area. NRC expects to close MF 2.02 (Erosion Control of the SDF Engineered Surface Cover and Adjacent Area) under performance objectives §61.41 and §61.42 after the NRC determines that the physical stability of the closure cap, engineered cover layers below the closure cap, and the land adjacent to the engineered surface cover is adequate. Given the importance of construction activities on the performance of the engineered surface cover, NRC does not expect to close MF 2.02 prior to completion of construction.

As discussed in this TRR, the NRC staff concerns about inadequate consideration of future scenario uncertainty were documented in past Request for Additional Information (RAI) Questions and/or in Onsite Observation Visit (OOV) Reports. Scenario uncertainty and conceptual model uncertainty are difficult to capture in dose models; however, they have the potential to dominate the uncertainty in dose projections. Additional analyses to reduce scenario uncertainty and conceptual model uncertainty could help staff understand the expected future performance better.

MF 10.02 addresses the uncertainty of conceptual models and analysis of potential alternative conceptual models under the assumption that present natural and environmental processes will remain unchanged over time. The NRC will monitor the DOE consideration of alternative conceptual models in a future performance assessment because of the potential importance of alternative conceptual models to dose projections.

While MF 10.02 describes monitoring activities regarding conceptual model uncertainties (i.e., different ways of modeling how the site will function based on current conditions), scenario uncertainties, which deal with potential alternative future evolutions of the site, are not described in the MF. Features, events, and processes associated with plausible alternative scenarios for the SDF will differ from the central scenario, which is the scenario that can best support the probable future dynamic evolution of the disposal site. For example, future erosion rates for land surrounding the SDF and the closure cap under different, yet plausible, climate conditions is a potential concern, so that future changes to vegetation, infiltration, and erosion may need to be evaluated more thoroughly by the DOE. For clarification purposes, and to distinguish more clearly between conceptual model uncertainty and future scenario uncertainty, this TRR recommends creating a separate MF on scenario uncertainty. MF 10.02 (Defensibility of Conceptual Models) on model uncertainty will not be revised. This TRR recommends creating MF 10.14, (Scenario Development and Defensibility) under MA 10 (Performance Assessment Model Revisions) under performance objectives §61.41 and §61.42. Under MF 10.14, the staff would monitor DOE consideration of plausible alternative scenarios in future performance assessment development because of the potential importance of plausible alternative scenarios to dose projections and continue to monitor the scenario development and defensibility of the central scenario. The NRC expects to close MF 10.14 after the DOE updates the performance assessment and the NRC determines that the evaluated scenarios are appropriate.

Enclosure:
Technical Review: Hydraulic Performance and Erosion Control of the Planned Saltstone Disposal Facility Closure Cap and Adjacent Area

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SUBJECT: TECHNICAL REVIEW: HYDRAULIC PERFORMANCE AND EROSION CONTROL OF THE PLANNED SALTSTONE DISPOSAL FACILITY CLOSURE CAP AND ADJACENT AREA (DOCKET NO. PROJ0734) **[DATE]**

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Technical Review of the Hydraulic Performance and Erosion Control of the Planned Saltstone Disposal Facility Closure Cap and Adjacent Area

Date

January 30, 2018

Reviewer

Hans Arlt, Sr. Systems Performance Analyst, U.S. Nuclear Regulatory Commission (NRC)

Primary Documents

U.S. Department of Energy (DOE), WSRC-STI-2008-00244, Rev. 0, "Saltstone Disposal Facility Closure Cap Concept and Infiltration Estimates," May, 2008. Agencywide Documents Access and Management System (ADAMS) Accession No. ML101600430

_____ SRR-CWDA-2009-00017, Rev. 0, "Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site," October 2009. [Referred to as the 2009 SDF PA] ADAMS Accession No. ML101590008

_____ SRR-CWDA-2013-00062, Rev. 2, "Fiscal Year 2013 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site," October 2013. [Referred to as the FY13 Special Analysis Document] ADAMS Accession No. ML14002A069

_____ SRR-CWDA-2014-00002, Rev. 1, "Crosswalk of Select Documents Related to the Monitoring Programs for the Saltstone Disposal Facility," February 2014. [Referred to as the 2014 SDF Crosswalk] ADAMS Accession No. ML14071A184

_____ SRR-CWDA-2014-00006, Rev. 2, "Fiscal Year 2014 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site," September 2014. [Referred to as the FY14 Special Analysis Document] ADAMS Accession No. ML15097A366

U.S. Nuclear Regulatory Commission (NRC), "Technical Evaluation Report for the Revised Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site, South Carolina," April 2012. [Referred to as the 2012 SDF TER] ADAMS Accession No. ML121170309

_____, "U.S. Nuclear Regulatory Commission Plan for Monitoring Disposal Actions Taken by the U.S. Department of Energy at the Savannah River Site Saltstone Disposal Facility in Accordance with the National Defense Authorization Act for Fiscal Year 2005," Rev. 1, September 2013. [Referred to as the 2013 SDF Monitoring Plan] ADAMS Accession No. ML13100A113

Background

Hydraulic performance and erosion protection of the closure cap at the Saltstone Disposal Facility (SDF) are described in the NRC 2013 SDF Monitoring Plan (ADAMS Accession No. ML13100A113) in Monitoring Factor (MF) 2.01 (Hydraulic Performance of Closure Cap) and MF 2.02 (Erosion Protection).

Conceptual model uncertainty addresses different ideas of how a site could function given current site conditions. The appropriateness of the conceptual model and alternative conceptual models are part of MF 10.02 (Defensibility of Conceptual Models). Scenario uncertainty is equally important; however, describes different possible site conditions that could develop because of future events and is currently not part of MF 10.02. This Technical Review Report (TRR) recommends that the appropriateness of the central scenario and plausible alternative scenarios be considered as part of a new MF 10.14 (Scenario Development and Defensibility).

Summary of Information from the DOE and the NRC Documents Prior to the DOE Fiscal Year 2014 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site (SRR-CWDA-2014-00006, Rev. 2)

This TRR addresses the performance of the engineered surface cover that DOE plans to use to limit infiltration and control erosion at the SDF. This TRR also addresses erosion process in the area immediately surrounding the SDF. For this report, the closure cap entails that part of the engineered surface cover that is simulated using the code HELP (Hydrologic Evaluation of Landfill Performance) and provides the upper boundary condition for the PORFLOW SDF vadose zone flow model. As shown in Figure 1, the closure cap design consists of vegetation and topsoil at the surface, the upper backfill, an erosion barrier of coarse stone, the middle backfill layer, the upper lateral drainage layer, the upper High Density Polyethylene (HDPE)/ Geosynthetic Clay Liner (GCL) composite layer, the foundation layer, and the upper part of the lower backfill layer. The term cover, as used in this report, includes the closure cap and additional layers including the lower backfill layer above the soils and those engineered cover layers found only above each Saltstone Disposal Structure (SDS) (i.e., the lower lateral drainage layer (LLDL) and a lower HDPE/GCL composite layer). In addition, although DOE and NRC documents frequently refer to a single cap, current plans anticipate two closure caps to be constructed over the SDF disposal units within the Z Area. The Saltstone Processing Facility will be located between the two closure caps and not be covered by either one of them.

The NRC staff reviewed the DOE 2009 SDF Performance Assessment (PA), the DOE document WSRC-STI-2008-00244, and other documents to prepare the NRC 2012 SDF Technical Evaluation Report (TER). Those DOE documents described the SDF being shielded by two closure caps that are designed to (1) provide physical stabilization, (2) limit infiltration by promoting runoff, evapotranspiration, and the shedding of water around the disposal structures, and (3) act as an intruder deterrent.

Figure 1: Conceptual illustrations of the components of SDF engineered cover (Figure 3.2-20 in SRR-CWDA-2009-00017, Rev. 0)

Monitoring Factor 2.01 Including Hydraulic Performance and Minimizing Infiltration
WSRC-STI-2008-00244 described the mean annual precipitation at the Savannah River Site (SRS) as approximately 48 inches per year (in/yr) [121 centimeters per year (cm/yr)], with a range of 35 to 72 in/yr [88 to 183 cm/yr]. Table 3 from WSRC-STI-2008-00244 provided additional water budget components for the SRS including a median value of 31.2 in/yr [79.2 cm/yr] for evapotranspiration from eight studies. Runoff had a range of 0.1 to 4 in/yr [0.3 to 10 cm/yr] with a median of 1.6 in/yr [4.1 cm/yr], and infiltration had a range of 5 to 32 in/yr [10 to 81 cm/yr] with a median of 14.8 in/yr [37.6 cm/yr].

In the 2009 SDF PA, the DOE did not assume any active maintenance will continue after the 100-year institutional control period post SDF closure. Although the DOE assumed that the two closure caps would initially be vegetated with grass, the vegetation was then assumed to evolve into a pine forest. The DOE used the HELP code to represent the closure cap layers and to estimate infiltration flux through the lower backfill layer by considering processes that degrade or alter the properties of the layer materials (e.g., root penetration of the HDPE geomembrane and clogging of drainage layers).

HELP simulations of infiltration by the DOE were based on a 100-year synthetic weather database for Augusta, Georgia that was modified with SRS-specific precipitation data. The annual precipitation in that data set ranged from 30 to 69 in/yr [76 to 175 cm/yr]. The simulated average annual net infiltration flowing through the bottom of the foundation layer was then used as an upper boundary condition for the PORFLOW SDF vadose zone model in the lower part of the lower backfill layer. Several sensitivity analyses were performed by the DOE with the HELP model including a case where hydraulic property values equivalent to that of backfill were assigned to each closure cap layer. In the 2009 SDF PA, the DOE presented those results to demonstrate that the sensitivity of the SDF performance to the closure cap would be limited. The DOE showed that the peak dose shifted only slightly earlier in time and the magnitude increased by less than 50 percent. Because only the closure cap layers were modified while the drainage layer and composite layer above the wasteform remained unchanged, the infiltrating water was effectively shed around the disposal structures. If the LLDL or the concrete roof of the disposal structure degraded in a way that changed hydraulic conductivity, then the performance of the closure cap would become more risk-significant. Accordingly, the 2012 SDF TER recommended that NRC staff should review information relevant to the assumed performance of the closure cap.

Although the contribution of the HDPE/GCL composite layer in the closure cap to the long-term performance of the closure cap (e.g., 6,000 years) after closure is minimal, the DOE assumed it to be a significant barrier to infiltration in the first several hundred years after site closure (WSRC-STI-2008-00244). Because the performance of the upper composite layer will be sensitive to construction quality and differential settlement, the 2012 SDF TER recommended that NRC staff should evaluate the Quality Assurance/Quality Control (QA/QC) for closure cap construction and review relevant studies and testing related to HDPE/GCL performance, including testing of the integrity of the seams.

As the upper lateral drainage layer degrades and time elapses, a greater portion of the infiltrating water will not be laterally drained and the DOE expects that the closure cap components above the upper HDPE/GCL composite layer will become saturated. The NRC staff identified in the 2012 SDF TER the concern that pore-pressure build up in the overlying closure cap layers could affect cover stability, vegetation, hydraulic performance of cover materials, and erosion. The DOE modeling indicated that an initial hydraulic head of 3.76 in [9.55 cm] was predicted to develop on top of the upper HDPE geomembrane and increase until the year 5,400 years, after which the hydraulic head was predicted to range from 39.0 to 40.0 in [99.0 to 100 cm] (SRR-CWDA-2011-00044). The DOE indicated that conservative modeling assumptions (e.g., depth of evapotranspiration zone and degradation of the lateral drainage layer) resulted in estimates of head on the HDPE geomembrane that are bounding and conservative. Should the buildup of hydraulic head occur, DOE does not believe it would adversely impact the physical stability of the closure cap, vegetation, erosion, or performance of the composite layer. The 2012 SDF TER stated that if an analysis containing more detailed simulations determined that the buildup of hydraulic head is realistic, an explicit evaluation of the physical stability of cover materials under this condition will be needed.

The 2012 SDF TER concluded that more model support was needed for the long-term infiltration-limiting performance of the closure cap due to the importance of infiltration to system performance.

Monitoring Factor 2.02 Including Intruder Barrier Stability and Minimizing Erosion

The ability of the cover to reduce infiltration, provide physical stability, and deter intrusion for long time periods is dependent on erosion controls. Erosion control will be necessary to ensure that a thick cover of soil is maintained over the waste for protection of inadvertent intruders and to provide suitable conditions for the vegetative cover. The current design consists of a minimum of 10 ft [3 m] of material above each disposal structure (see Figure 2 taken from WSRC-STI-2008-00244). Although the DOE does not assume the erosion barrier layer will prevent tree root penetration, or prevent erosion of the topsoil and upper backfill layer, the erosion barrier is designed to limit surface water erosion of the underlying layers. In addition, the DOE expects that the design, construction, and performance of the erosion barrier should prevent direct contact of the waste by potential inadvertent intruders and animal intrusion into the lower layers. Aspects of the closure cap designed to prevent gully erosion and limit soil loss were based on scoping calculations.

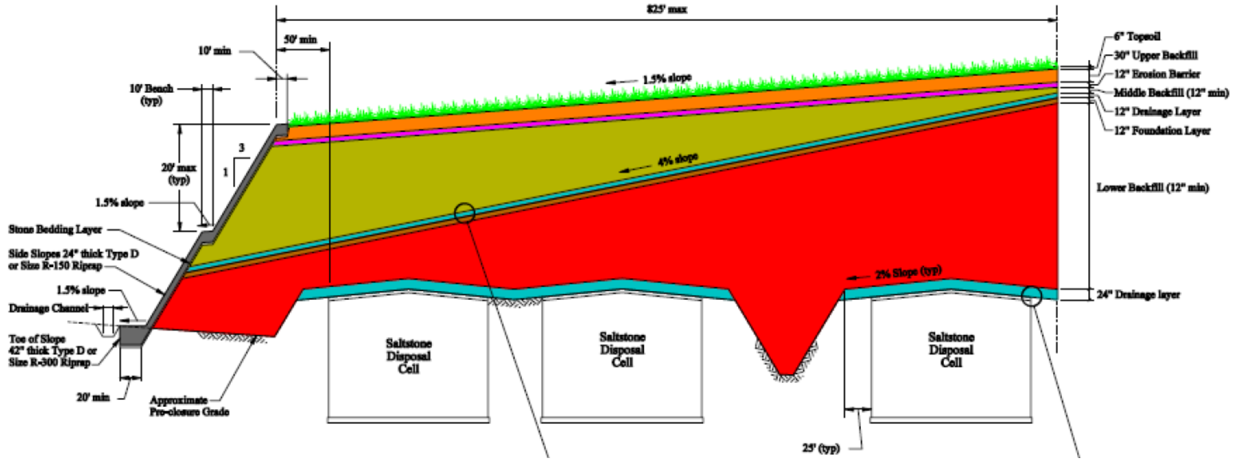

Figure 2: Conceptual Illustration of the SDF Closure Cap Layers Configuration (Figure 8 in WSRC-STI-2008-00244)

The DOE determined the projected long-term topsoil loss according to the Universal Soil Loss Equation for both vegetative cover conditions (i.e., Bahia grass then being succeeded by pine forest). The DOE predicted approximately 1.3 in [3.3 cm] of soil loss for the topsoil and no reduction in the upper backfill layer within 10,000 years (WSRC-STI-2008-00244; Section 7.2). Riprap for the integrated drainage system ditches has not yet been sized due to the early phase of the cover design and lack of a detailed closure cap drainage system layout. Riprap material for the erosion barrier, side slope, and toe of the side slope will be selected from local granite or mylonitic quartzite quarries. In the 2013 SDF Monitoring Plan, the NRC staff expressed concern that if a rock source is not available that can adequately resist weathering, then modifications to the closure cap or assumptions regarding performance of the closure cap, or both, may be needed. Those modifications may be more easily accommodated earlier in the closure process. Although the DOE indicated that the design information was sufficient for planning purposes and that rock sources will be evaluated in the final closure cap design, the NRC staff recommended in the Technical Notes for MF 2.02 in the SDF Monitoring Plan (ADAMS Accession No. ML13100A113) that a preliminary evaluation of rock sources be conducted to provide confidence that an acceptable rock source is available.

The DOE evaluated the physical stability of the closure cap with respect to a probable maximum precipitation (PMP) event (WSRC-STI-2008-00244). The PMP is defined as the theoretically greatest depth of precipitation that is physically possible during a given period of time over a given area at a particular geographic location. To mitigate the potential effects of erosion by surface water, erosion protection designs must be based on an appropriately conservative rainfall event. The DOE determination of the PMP event and the corresponding design criteria for the vegetative layer, erosion barrier, side slopes, and toe of the side slopes were consistent with the NRC guidance document NUREG-1623 (ADAMS Accession No. ML022530043) which addresses a 1,000-year timeframe. The design parameters are widely used in the engineering community and by other Federal agencies, and the design approaches have been applied at various disposal sites. The NRC staff considers that the guidance provided may be used for nearly all types of erosion protection designs; however, each design should be informed by the specific characteristics of the site and the waste and its intended purpose (e.g., long-lived waste may require a greater emphasis on rock durability). DOE stated that the SRS-specific PMP has a low probability of occurrence and is a bounding event, thereby providing assurance of physical stability of the closure cap design for a 10,000-year compliance period (SRR CWDA-2011-00054; SRR CWDA-2009-00054), and that the PMP is not likely to change significantly in a wetter climate, based on the conservatism associated with the estimation of the PMP. The NRC's 2012 SDF TER stated the PMP to be a very unlikely event with respect to low-level radioactive waste disposal, and that the PMP is appropriate to use to produce a conservative design. In Section 2.4.3.2 of the 2012 SDF TER, the NRC staff determined that DOE estimates for the PMP were reasonable, the probability of such an event being equaled or exceeded was very low, and thus, the PMP provided a reasonable design basis for evaluating the vegetative cover, erosion barrier, side slopes, and toe of the side slopes.

The DOE responded in SRR-CWDA-2010-00033 to an NRC staff concern with the long-term performance of the side slopes expressed in the Request for Additional Information (RAI) Infiltration and Erosion Control (IEC)-3 and documented in ML100820101 by reiterating that both the erosion barrier riprap and the side slope riprap had been sized based upon the PMP and the methodology of NUREG-1623. However, the NRC concern had focused more on the subflow from the closure cap drainage layer flowing through the side slope riprap, which could significantly increase the water content of the backfill beneath the side slope and lead to slumping, than the concern the DOE addressed in their response (i.e., the ability of flow resulting from the PMP event to move the riprap). The DOE acknowledged that slumping of the side slope and down-slope creep of the riprap were not evaluated explicitly; however, the DOE indicated that the conservatisms in its approach to designing the side slopes are expected to account for any potentially adverse effects of additional degradation mechanisms. In addition, DOE indicated that slope stability will be considered as part of the closure cap final design (SRR-CWDA-2010-00033; Response IEC-3).

The NRC staff concluded in the 2012 SDF TER that the closure cap, as designed, can provide adequate long-term erosion protection. However, because the cap will not be built until SDF closure, the DOE needs to demonstrate that certain aspects of the design can be implemented (e.g., an acceptable rock source will be available) and that the designed performance can be achieved (e.g., that adverse effects of head buildup over layers can be prevented). For example, long-term maintenance of the topsoil and vegetative cover is important to closure cap performance because the average evapotranspiration rate (32.6 to 33.6 in/yr [82.7 to 85.4 cm/yr]) dominates the modeled water balance distribution for SRS average annual precipitation (49.1 in [125 cm]). The calculations for determining the susceptibility of a Bahia grass cover closure cap to the initiation of gullying was evaluated using the methodology in NUREG-1623 based on a PMP event. However, the DOE did not evaluate the potential cumulative effects from less significant but more frequent precipitation events on gully formation over long time periods. The 2012 SDF TER stated that an evaluation of the cumulative effects from precipitation events over long time periods with respect to gully formation was needed to support predictions of long-term performance of the topsoil and vegetative layers. In addition, the 2013 SDF Monitoring Plan recommended that the stability of a degraded vegetative cover should be evaluated because the Bahia grass, bamboo, or pine forest could be degraded by fire or extended drought, which could adversely affect the ability of the vegetative and topsoil layers to resist erosion.

As discussed in the 2012 SDF TER, although the design will not be final until closer to the time of SDF closure, timely verification is needed to show that certain designed features can be implemented as intended to allow sufficient time to incorporate closure cap design changes or, if necessary, reexamine assumptions regarding its long-term performance. Potential modifications may be important in the overall evaluation of closure cap performance.

<u>Summary of Information from the DOE and the NRC Documents Since the DOE Fiscal Year 2014 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site (SRR-CWDA-2014-00006, Rev. 2) from September 2014</u>

The DOE fiscal year (FY) 14 Special Analysis Document evaluated the significance of new information pertaining to changes in future SDS design from the 150-ft [45.7-m metric equivalent applicable for the rest of the document] diameter structures to 375-ft [114-m metric equivalent applicable for the rest of the document] diameter structures (e.g., SDS 6). The document also evaluated changes in the modeled inventory for all disposal structures and the elimination of the clean cap on top of the saltstone for the 150-ft and 375-ft diameter structures. Some of these changes are part of the technical topics reviewed under MA 2 and summarized below. Four Onsite Observation Visits (OOVs) were conducted by the NRC since the document was published and information pertaining to infiltration and erosion from those OOVs is summarized below.

The FY14 Special Analysis Document stated that seven 375-ft diameter disposal structures will be constructed so that there will be 15 disposal structures in total: two rectangular vaults SDS 1 and SDS 4, six 150-ft disposal structures (i.e., SDS 2A, SDS 2B, SDS 3A, SDS 3B, SDS 5A, and SDS 5B), and expected seven 375-ft structures (SDS 6 through SDS 12). The nominal interior diameter of the new disposal structures is to be 375 ft, with an interior height of 43 ft [13 m]. The floor and the roof both have a 1.5 percent downward slope from the center of the structure. The 43 ft [13 m] of saltstone poured into the disposal structure through a roof penetration contrasts with the 22 ft [6.7 m] of saltstone within the six 150-ft diameter disposal structures. The perimeters of the two sections of the closure cap shown in Figure 3.2-2 of the FY14 Special Analysis Document are unchanged from those shown in Figure 5 of WSRC-STI-2008-00244 indicating that the design for the closure cap was unchanged. In addition, Section 3.3.2 in the document states that the conceptual design of the closure cap remains unchanged since 2008.

<u>Monitoring Factor 2.01 Including Hydraulic Performance and Minimizing Infiltration</u>

The NRC staff evaluated the DOE information in the FY14 Special Analysis Document and documented questions and comments in “NRC Staff Request for Additional Information [RAI] Questions on the Fiscal Year 2014 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site (SRR-CWDA- 2014-00006, Rev. 2)” (NRC RAI Questions on the FY14 Special Analysis Document in ADAMS as Accession No. ML15161A541). The DOE responded to the NRC RAI questions with the DOE document, “Comment Response Matrix for NRC Staff Request for Additional Information on the Fiscal Year 2014 Special Analysis for the Saltstone Disposal Facility at the Savannah River Site” (SRR-CWDA-2016-00004, Rev. 1). One part of the RAI Question Infiltration and Erosion Control (IEC)-1 concerned the field flow uncertainty and the sampling distribution for probabilistic modeling included in the FY14 Special Analysis Document where the NRC requested that the DOE provide a technical justification for the assumed expectation that future infiltration rates will be between the minimum and average values DOE projected in that document.

The DOE indicated in the FY14 Special Analysis Document that the distribution was justified because of the number of conservatisms assumed in the development of the HELP model to generate the infiltration rates, as discussed in WSRC-STI-2008-00244. Giving credit for those conservatisms, the FY14 Special Analysis Document stated that it was reasonable to expect that future infiltration rates would be between the minimum and average values. However, the staff determined in ADAMS Accession No. ML15161A541 that the expected conservatisms in the HELP code were not adequate justification given the concerns about the reliability of HELP for predicting performance without site-specific calibration. In the DOE's response to RAI Question IEC-1, the DOE described the conservatisms from WSRC-STI-2008-00244 that informed the assigned probabilities in more detail. The DOE also indicated that the deterministic Evaluation Case assumes the average infiltration rate and was not affected by the probabilistic modeling with GoldSim, and that after a formal closure cap design is finalized, such assigned probability weightings will be reevaluated.

Another part of RAI Question IEC-1 requested the DOE to provide an update to the HELP code replacement evaluation. As discussed in the NRC 2016 OOV report, a National Research Council assessment stated that the HELP code provides relatively poor predictions of the performance of earthen final covers (National Research Council, 2007) and is not capable of appropriately considering the results of the probability-based root penetration model, which has been developed to evaluate root penetration of the GCL through tensile stress cracks within the overlaying HDPE geomembrane. For that reason, the DOE stated that other codes would be evaluated as a replacement to the HELP code, including, but not limited to, FEHM, HYDRUS-2D, LEACHM, TOUGH-2, UNSAT-H, and VADOSE/W. As described in SRR-CWDA-2016-00004, the DOE evaluated computer codes used to predict percolation of water through the closure cap and into the waste containment zone. That work compared the HELP model with alternative computer codes that use the Richards' equation for unsaturated flow and resulted in two recommended codes for further evaluation: HYDRUS-2D3D and VADOSE/W. For a simple no-cover scenario (Sandy Clay soil type and grass cover), HYDRUS-2D3D produced an infiltration estimate of 17.6 in/yr [44. 7 cm/yr]. For a similar problem specification, the HELP model produced an estimate of 9.8 in/yr [25 cm/yr]. The DOE stated that both model predictions are within the range of infiltration estimates generated from field measurements and other modeling studies for similar conditions. Currently, the DOE is still in the process of evaluating the various codes and possible systemic biases in the HYDRUS-2D3D code relative to HELP and/or field measurements for SRS applications so that a decision has not yet been reached as to if and when the HELP code might be replaced. In the meantime, although the HELP model does not automatically integrate with the root penetration model, the DOE stated that by combining the HDPE and GCL layers and applying penetrations through the combined HDPE/GCL with the number of holes increasing over time starting as early as year 300 after closure, the HELP model compensates for the model's inability to fully integrate the probability based root penetration model.

RAI Question IEC-1 was also discussed during the NRC OOV in April 2016 and the discussion was summarized in the OOV report (ADAMS Accession No. ML16147A197). With regard to the general suitability of the HELP computer code and the DOE evaluation of other possible computer codes to replace the HELP computer code, the NRC staff indicated that, although no computer code will be perfect for what is needed by the DOE, some computer codes will be better suited than others and the HELP computer code has numerous critics. For example, critical remarks can also be found on pages 81-82 in the National Research Council's 2007 "Assessment of Performance of Engineered Barriers."

The NRC 2016 OOV report also discussed the DOE sensitivity analyses on precipitation and infiltration rates. The DOE ran multiple simulations with the HELP code using annual precipitation values ranging from a minimum of 29.8 in/yr [75.7 cm/yr] to a maximum of 68.6 in/yr [175 cm/yr]. Sensitivity analyses were described in the 2009 SDF PA and both the FY13 and FY14 Special Analysis Documents using the maximum infiltration value derived from that maximum precipitation value. However, Figure FFT-1.3 from SRR-CWDA-2016-00004 (see Figure 3 below) shows that the maximum precipitation value or the precipitation data set range that is used in the HELP model may need to be reevaluated. Figure 3 below also shows the plot of water levels in Well ZBG 2 in the Z Area versus historical rainfall. It is a comparison of water level readings over time for Well ZBG 2 to the moving one-year average rainfall for the nearest rainfall monitoring station in H Area. The moving one-year average rainfall for the H Area, located less than a mile south of the Z Area, shows averages that lie above the maximum annual precipitation value of 68.6 in used in the HELP model (WSRC-STI-2008-00244, Table 9). In addition, the moving one-year average rainfall for the H Area also lie above the 1964 annual precipitation of 73.06 in [185.6 cm] measured at the combined Savannah River National Laboratory/Central Climatology Site weather stations (WSRC-STI-2008-00244, Table 6) and the 1964 annual precipitation of 71.74 in [182.2 cm] measured at the 200-F weather station (WSRC-STI-2008-00244, Table 7). During the 2016 OOV, the NRC and DOE discussed additional information that might be included in the next revision of the SDF PA. Those possible revisions included updates to the meteorological data used to calculate expected ranges for infiltration in the near future that reflect uncertainty in the current dataset from the last 50 years and also infiltration projections that reflect the uncertainty in future climate states.

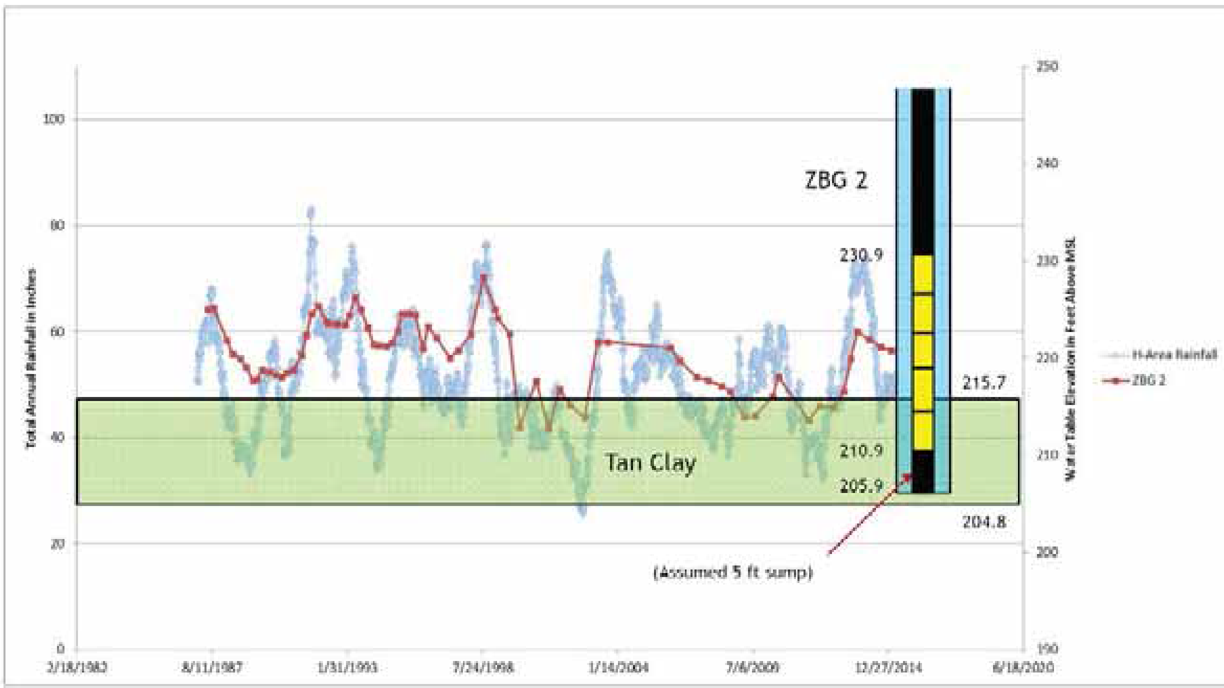

Figure 3: Plot of Historical Rainfall vs. Water Levels in the Z-Area Well ZBG 2 (Figure FFT-1.3 from SRR-CWDA-2016-00004)

The NRC RAI Question Performance Assessment Method (PAM)-4 (ADAMS Accession No. ML15161A541) addressed uncertainty about the future of the SDF as the result of an inherent lack of knowledge about how the SDF will evolve over time. The future climatic or geologic conditions that will prevail at the SDF are not known; however, the performance assessment process for long-lived waste requires consideration of possible future conditions. For example, climatic variation may significantly change groundwater flow pathways over time, or net depositional or erosional changes at the site may cause risk-significant changes to site performance. The DOE did not provide an analysis of scenario uncertainty or an evaluation of possible future conditions at the site in the FY14 Special Analysis Document. The DOE responded to RAI Question PAM-4 in SRR-CWDA-2016-00004 by stating that the only likely scenario that would result in potential impacts to the SDF conceptual model of hydrologic flow would be a significant increase or decrease in rainfall that could impact the thickness of the vadose zone. However, the DOE continued by stating that changes in the thickness of the vadose zone due to changing meteorological conditions would only be in the range of tens of feet, so that radionuclide travel times to exposure points would only be shortened by a couple of years as opposed to 100s or 1,000s of years. The DOE also performed a sensitivity analysis (SRR-CWDA-2014-00095) to assess the relative impact from varying the saturated zone thickness over the expected range of thickness and found very little impact.

Monitoring Factor 2.02 Including Intruder Barrier Stability and Minimizing Erosion

The SDF and the future closure caps will be built on the current Z Area and supported by the surrounding land. That land is composed of unconsolidated soils and sediments with the potential to erode relatively quickly given the right conditions. Severe erosion and gully growth in the land surrounding the Z Area in the future could have the potential to disturb the closure cap and allow environmental surface processes to more quickly reach the saltstone. Due to the potential importance of controlling erosion of the surrounding area to the performance of the engineered surface barrier, during the 2017 OOV, the NRC staff examined the land surrounding the Z Area including the steeper valley slopes and any left-bank tributaries (i.e., the bank closest to the SDF) for indications of sheet and rill erosion and gully growth. Evidence of past gully activity was found; however, the gully in question had vegetation growth within it, including older trees, and was covered with leaf debris despite recent heavy rainfall. Thus, no active gully erosion was evident and the gully formation appears to have occurred at an earlier time. In addition, no large-scale sheet or rim erosion was evident outside the Z Area; the topsoil is intertwined with fine roots so that erosion is not occurring in any visible manner.

Future Scenario Uncertainty as It Relates to Infiltration and Erosion

During the 2016 OOV, the NRC and DOE discussed additional information that might be included in the next revision to the SDF PA. That information included erosion projections that reflect the uncertainty in potentially different climate states in the future as well as associated erosional analyses of potentially different climate states. The NRC and DOE discussed that those analyses could be similar to the analyses in the “Erosion of the Soil above the Erosion Barrier” section in Appendix I of WSRC-STI-2008-00244 or could be similar to the analysis in pages 305-307 in WSRC-STI-2007-00184. All current erosional analyses are tied to the assumption that two species will dominate the cover over the next 10,000 years: the tropical to subtropical Bahia grass (*paspalum notatum*) for the first few hundred years and then the loblolly pine (*pinus taeda*) for the next more than 9,000 years. During discussions related to the RAI Question PAM-4, the NRC staff pointed out the importance of obtaining more information in order to bound the uncertainty associated with different climate states. Variations in the temperature and rainfall may occur over a 10,000 or a 1,000 year timespan and the species that dominate the closure cap may change with differing climate states (e.g., drier periods may cause more fires and if wildfire suppression is no longer occurring other species may begin to dominate).

NRC Evaluation

Monitoring Factor 2.01 Including Hydraulic Performance and Minimizing Infiltration

The NRC staff evaluated the DOE response to RAI Question IEC-1 on the FY14 Special Analysis Document including the conservatisms used as the rationale to assign overall higher probabilities to the lower infiltration rates rather than the given average future rates.

In response to the NRC concerns about the range of precipitation values used to calculate infiltration, one such DOE conservatism stated:

> The precipitation data included significant pulses of water, not just average values, by utilizing a range of daily precipitation from 0 inches up to 6.7 inches and an annual range from 29.8 inches to 68.6 inches.

However, the NRC staff disagrees that the use of these average values constitutes a conservatism in the model because those are measured rainfall values, not projected conservative values.

In addition, the range of daily precipitation was not used in the HELP model. As stated in Section 7.9 in the DOE document WSRC-STI-2008-00244: "It is evident that while large pulses of precipitation do impact daily infiltration, there is little impact under intact closure cap conditions, and the daily infiltration is much less than precipitation, even under degraded closure cap conditions. Therefore using average annual infiltration rates based upon the precipitation data set is considered appropriate." The NRC staff reviewed the DOE information and, although the staff agrees that daily infiltration is much less than daily precipitation even under degraded closure cap conditions, the difference between the two rates is not an adequate basis for neglecting the potential effect of higher daily precipitation rates on performance. Although the amount of infiltrating water may be less than the original pulse of rainwater, a relatively large pulse of infiltrating water could mobilize contaminants in unforeseen ways. The NRC staff determined that a DOE sensitivity analysis could help to determine the significance of incorporating pulses of episodic precipitation into the model.

Another DOE conservatism stated:

> The maximum slope length of the closure cap (i.e., 825 feet) was used to determine both runoff and lateral drainage for the entire cap. A significant portion of the cap will have slope lengths less than 825 feet, resulting in more runoff.

Comparing the results of average water balance components in Table 47 in WSRC-STI-2008-00244 with those from Table 80 in WSRC-STI-2007-00184 show that the modeled runoff rates are greater for the SDF closure cap than they are for the F-Tank Farm closure cap after 5,000 years although the F-Tank Farm closure cap has a shorter slope length (585 ft [178 m]) and a greater slope (2 percent). NUREG/CR-7200 (ADAMS Accession No. ML16125A124) stated that erosion is greater for longer slopes and slopes with a large-grade difference at the nickpoint between the top and side slopes, and that slope lengths should be kept as short as practical and grade differences as small as practical to reduce erosion. NUREG/CR-7200 further stated that terraced slopes with an armored surface cause a smaller erosion rate in a humid climate due to the use of many short slope lengths. This indicates that having shorter slope lengths should not result in more runoff.

The model results of the latter half of the 10,000-year model run differ in several ways between the closure caps for the SDF and the F-Tank Farm. Although evapotranspiration for the SDF closure cap shows a difference of 1.09 in/yr [2.77 cm/yr] between 3,200 and 5,400 years, there is no such modeled increase for the F-Tank Farm closure cap. The runoff values for the SDF closure cap increase significantly between 3,200 and 5,412 years, from 0.77 to 4.42 in/yr [2.0 and 11.3 cm/yr] while the runoff rate for the F-Tank Farm remained constant at around 2.5 in/yr [6.4 cm/yr]. As discussed above, the rate of runoff for the latter 5,000 years is relatively high on the SDF closure cap, especially when compared to nominal average runoff values ranging from 0 to 2 in/yr [0 to 5 cm/yr] obtained from SRS water balance and infiltration studies and presented in Table 2 (WSRC-STI-2008-00244). Table 3 of WSRC-STI-2008-00244 presented a range of runoff rates (0.1 to 4.1 in/yr [0.3 to 10 cm/yr]) from one study. The DOE provided one possible explanation for the model result discrepancies in Section 7.9 of WSRC-STI-2008-00244 that stated that pluggage of the lateral drainage layer resulted in somewhat slower soil water drainage in the overlying soil layers. However, for a significant increase in runoff to occur at the surface, all the layers above the upper lateral drainage layer would need to be saturated up to the surface, which could potentially present problems related to stability. As previously discussed in this TRR, SRR-CWDA-2011-00044 indicated that saturated conditions are expected to occur above the upper HDPE/GCL composite layer with a saturated thickness ranging from 39.0 to 40.0 in [99.0 to 100 cm] from 5,400 to 10,000 years, but not up to the surface. Because saturated conditions at the surface would increase concerns of geotechnical stability, the DOE should document modeled moisture content for each layer over time, and if saturated conditions exist, evaluate the physical stability of the cover materials.

The NRC determined that another possible cause for the relatively high runoff values (up to 4.42 in/yr) [up to 11.3 cm/yr] for the last half of the 10,000-year time period is the entry value for vegetation as one of the HELP input values to determine runoff. In Section 5.5 in WSRC-STI-2008-00244, the DOE discussed those input parameters including vegetation and determined that an option representing a “good stand of grass” was most appropriate. Section 7.8 states that both the general and runoff input data developed in Section 5.5 is applicable to both the initial, intact, and the degraded SDF closure cap conditions. The NRC determined that, while this may be true for the first few hundred years, it is most likely not true for the following thousands of years since pine trees are assumed to be the dominant vegetation during this time period. If grass is the only vegetation criterion to choose from, a more realistic description of grass in a pine forest would have to be either “bare ground” or “poor stand of grass” since grass is not normally prevalent in pine forests. The NRC determined that a sensitivity analyses would help to determine if this is indeed a significant parameter; however, in combination with the relatively low saturated hydraulic conductivity of the HELP model default soil texture chosen in Section 5.4.1 (WSRC-STI-2008-00244), it may contribute to the 5,000 years of relatively high surface runoff rates.

Another DOE conservatism stated:

> The erosion barrier is assumed to be infilled with a sandy soil; the use of a less permeable infill would reduce infiltration. No lateral drainage is assumed to occur over the erosion barrier; however such lateral drainage could occur, particularly if a low permeable infill were used.

Appendix F in WSRC-STI-2008-00244 discussed the hydraulic properties for two different types of material being considered to be placed between the gravel stones that that will make up the erosion barrier: controlled low strength material (CLSM) and sandy soil. The matrix of an individual granite stone itself was considered impermeable and nonporous; however, the porosity of a layer of broken granite pieces was given in Appendix F as 38 percent. The hydraulic properties of the infill were multiplied by that percentage to give the resultant hydraulic properties. As indicated in the DOE response to RAI Question IEC-1, while sandy soil would yield a resultant saturated hydraulic conductivity of 1.3×10^{-4} cm/s, an erosion barrier filled with CLSM would yield only 8.36×10^{-7} cm/s, which greatly increases the chance of lateral flow occurring on top of the erosion barrier. The staff assumes that there is a likelihood that, until larger roots of trees would eventually break apart the erosion barrier and increase the hydraulic conductivity, lateral flow on top of the erosion barrier and associated risks to stability could occur. Saturated conditions at the surface would increase concerns of geotechnical stability. For example, one concern involves the volume of lateral flow that would exit at the upper reaches of the side slope above the erosion barrier and then add to and increase the current modeled flow rate on the side slope. Additional concerns would include the stability of the outer edges of the upper backfill layer as the backfill material may be carried out by the lateral flow into the side slopes. Over time the outer edges of the closure cap may begin to slump as backfill material is washed out from underneath. An explicit evaluation and description of the moisture content for each layer over time and of the physical stability of cover materials if saturated conditions existed could demonstrate whether instability caused by saturation of the cover should be explicitly considered as an expected or alternative conceptual model.

Although Section IEC-7 in SRR-CWDA-2011-00044 stated that slope stability should not be an issue even with a build-up of head, that section provided no reference or calculations to support that statement. Section IEC-7 of SRR-CWDA-2011-00044 also stated that none of the nominal saturations listed pose a problem to plant health in terms of root drowning although this statement also had no references or supporting calculations. Moisture contents or saturation levels above those of the surrounding forest may deter growth of the loblolly pine and promote vegetation more acclimated to moister soils.

Additional DOE conservatisms stated:

> The initial saturated hydraulic conductivity of the GCL was taken as 5.0×10^{-9} cm/s even though test results indicate that the value should be significantly lower."
> "It has been assumed that the GCL saturated hydraulic conductivity increases to 5.0×10^{-8} cm/s at the end of the 100-year institutional control period. This is not likely since infiltrating water at SRS should be very low in dissolved calcium and other divalent cations.

The initial saturated hydraulic conductivity of the sodium bentonite GCL of 5.0×10^{-9} cm/s was used for modeling purposes by the DOE only for the first hundred years. Thereafter, the DOE assumed an exchange of sodium with divalent cations such as calcium and magnesium and model hydraulic conductivity values were obtained using information from Section 6.7.5 in WSRC-STI-2008-00244 based on calcium bentonite studies including a saturated hydraulic conductivity of 4.0×10^{-9} cm/s determined for a 45 year old calcium bentonite field installation at SRS. The DOE chosen saturated hydraulic conductivity value of 5.0×10^{-8} cm/s is more conservative than assuming no exchange with divalent cations; however, the DOE assumed value may not be significant to performance at and beyond 300 years. From that time on forward, the HDPE geomembrane and GCL are modeled as a combined layer with a saturated hydraulic conductivity of 8.7×10^{-13} cm/s and a thickness of 0.26 in [0.66 cm]. The resulting combined saturated hydraulic conductivity of the HDPE and the GCL layers was obtained using the equation on page 243 in WSRC-STI-2008-00244 (see below), and the resulting value is strongly influenced by the layer with the lower hydraulic conductivity and the thickness of that layer. For example, if the conservative saturated hydraulic conductivity value for the GCL was assigned an even more conservative value than DOE's assumed value (i.e., from 5.0 x 10^{-8} cm/s to 1 cm/sec), the resulting combined hydraulic conductivity would be only be changed from 8.7 x 10^{-13} cm/s to 8.8 x 10^{-13} cm/s. On the other hand, a difference of just 0.001 inch in the thickness of the HDPE geomembrane from 0.060 to 0.059 inches would also result in a combined hydraulic conductivity equal to 8.8 x 10^{-13} cm/s. The input property values of the HDPE geomembrane, and not the GCL, are the determining factors controlling the infiltration rate through the combined HDPE/GCL composite layer.

Equation from WSRC-STI-2008-00244, Appendix I, Page 243

$$K_v = \frac{d}{\sum_{i=1}^{n} d_i / K_i},$$

where K_v = combined saturated hydraulic conductivity of combined layers; d = total thickness of all layers combined; di = thickness of i^{th} layer; K_i = saturated hydraulic conductivity of i^{th} layer

At 300 years and beyond:

$$K_v = \frac{0.20'' + 0.060''}{\frac{0.20''}{5E-08\ cm/s} + \frac{0.060''}{2E-13\ cm/s}} = 8.7E-13\ cm/s$$

An additional reason the DOE may have made an optimistic assumption pertains to changing the saturated hydraulic conductivity value of the 0.2 in (5 mm) thick GCL to that of the property value of the combined layer. It is unclear if a 0.2 in (5 mm) bentonite layer protected by geotextile would survive intact as a recognizable layer for 10,000 yr. Bioturbation, or possibly settlement, may reduce the distinctiveness of the GCL as a separate layer as reworking of the backfill soils by small fauna and flora slowly integrate the bentonite above into the backfill below. As it is currently assumed for modeling purposes, the hydraulic conductivity of 5 x 10^{-8} cm/s for the single GCL layer is changed, together with the HDPE, to a combined hydraulic conductivity value of 8.7 x 10^{-13} cm/s that lasts for 10,000 years. Again, the NRC determined that sensitivity analyses would be helpful to recognize the significance of such assumptions and changes.

As previously discussed, the DOE, in response to the NRC concerns about using the HELP code (see RAI Question IEC-1), stated:

> For a simple no-cover scenario (Sandy Clay soil type and grass cover), HYDRUS-2D3D produced an infiltration estimate of 17.6 in/yr. For a similar problem specification (United States Department of Agriculture Soil Classification soil and fair stand of grass), the HELP model produced an estimate of 9.8 in/yr. Both model predictions are within the range of infiltration estimates generated from field measurements and other modeling studies for similar conditions.

Based on this example, the DOE appears to be relying on the code (i.e., HELP) that is less conservative than others, although the DOE has stated that they are continuing to evaluate the merits of using HYDRUS-2D3D over HELP for cover system scenarios (SRR-CWDA-2016-00004). The difference between those model results could result in an increase in the projected peak dose if the more conservative code is used.

Although the FY14 Special Analysis Document stated that the conceptual design of the closure cap remains unchanged, due to the increased size of the newer 375-ft diameter disposal structures, some type of change to the conceptual design of the closure cap may be necessary

to account for the additional height (i.e., 43 ft (13 m) versus 23.5 ft (7.2 m) maximum internal height) unless the bases of the 375-ft disposal structures are lower in elevation than shown in Figures 6 and 7 in WSRC-STI-2008-00244. The increase in internal height of the 365-ft disposal structures represents an increase of approximately 20 ft (6.1 m), which may require some aspect of the closure cap design to change if any 375-ft disposal structure is to be located close to the perimeter of the closure cap. For example, SDS 7 or SDS 11 will be relatively close to the outer edge of the closure cap based on designs seen in Figure 4. Even if SDS 7 is built at 265 ft (81 m) above mean sea level, the thickness of the lower backfill will likely need to be increase if the slope of the upper lateral drainage layer is to be maintained, and therefore, the height of the side slope would need to be increased. If the conceptual closure cap design is to stay as close to the original design as possible, and if the minimum surface thickness of 10 ft [3.0 m] of non-waste material above the waste material and a minimum thickness of 1 ft [0.3 m] of middle backfill and 1 ft [0.3 m] of lower backfill are to remain, the engineered cover may be higher than previously modeled. If the cover is higher than previously modeled, the side slopes will be higher in elevation and an additional bench may be required. The other alternatives to avoid higher side slopes would be to increase the slope of the upper lateral drainage layer or to increase size or area of the closure cap; the longer the slope, the lower the top part of the side slope will be. Alternatively, the thicknesses of the individual layers could be changed. For example, currently the HELP model and the PORFLOW model have a lower backfill minimum thickness of 72 in [180 cm] over the roofs of the disposal structures. So that the engineered cover does not become too big or too high, a future design could include a thinner minimum lower backfill layer over the cells. However, unless the base of the disposal structures are constructed at sufficiently deeper elevations, all alternatives involve changing the design in some way with the consequence that a majority of infiltration and erosion calculation results as documented in
WSRC-STI-2008-00244 would need to be reassessed and most likely reanalyzed and recalculated. It is possible that the southern part of the closure cap (right side of Figure 5) may not need such recalculations if tall disposal structures such as SDU 10, 11, and 12 as identified in Figure 5 are not built.

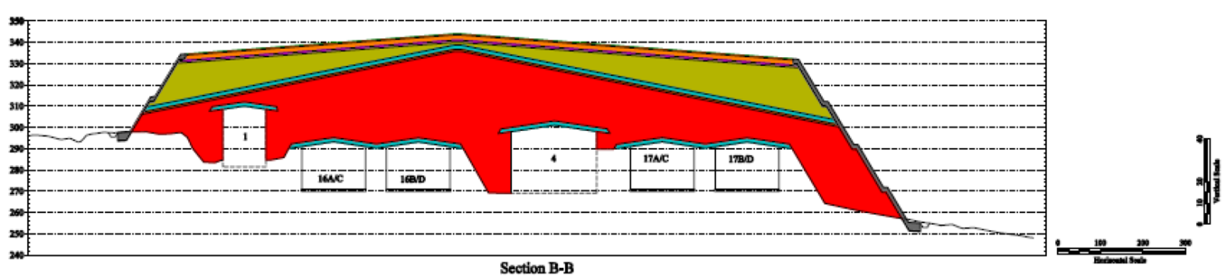

Figure 4: Conceptual Illustration of a Cross-Section from the SDF Engineered Cover Design (Figure 6 [Section B-B' from Sheet 1] in WSRC-STI-2008-00244)

A taller or larger closure cap would require more material, most likely material that makes up the middle and/or lower backfill. Currently the maximum designed thickness of the middle backfill layer is 20.6 ft [6.28 m], while the maximum design thickness of the lower backfill layer is envisioned to be nearly twice as thick (see Figure 4). If the borrow material that makes up most of the backfills requires some modifications to meet design specification (e.g., sand or clay to increase or decrease the hydraulic conductivity, respectively), then the NRC staff would consider this an important technical modification to the design and would need to evaluate the impact of the size, quality, and location of the source of the borrow area or areas.

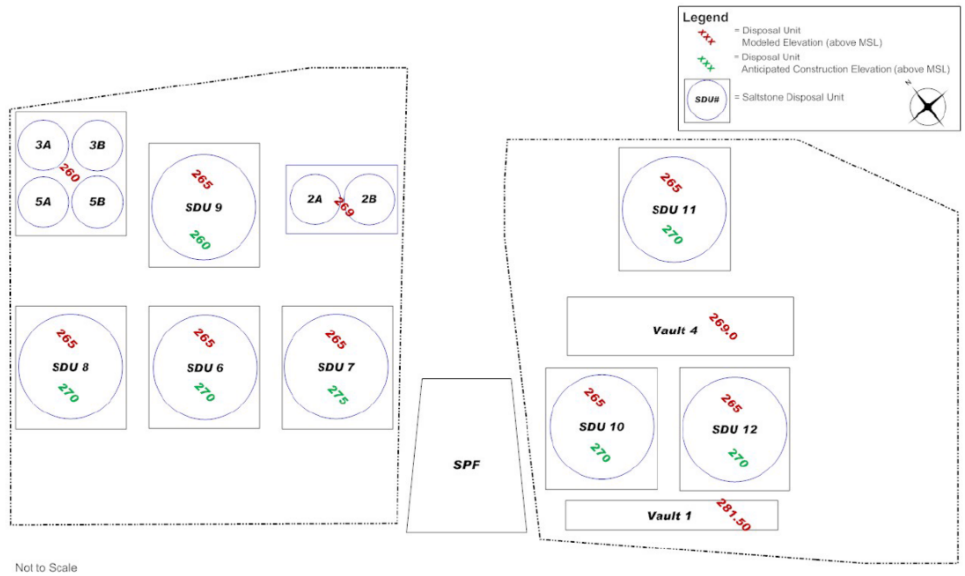

Figure 5: Layout of Disposal Structures (Figure 3.2-2 in the FY14 Special Analysis Document)

The analysis of the closure cap for the F-Tank Farm (WSRC-STI-2007-00184) presented an alternative degradation conceptual model of the upper lateral drainage performance as compared to the conceptual model considered for the SDF. The degradation concept for the F-Tank Farm was that colloidal clay migrates with the water flux from the middle backfill to the underlying lateral drainage layer. After half the clay content of the backfill has migrated to the drainage layer, the two layers essentially become the same material with the same properties. The endpoint saturated hydraulic conductivity was calculated to be that of the log mid-point between the initial backfill and drainage layer conditions. However, the SDF conceptual model (i.e., the silting-in concept for the Upper Lateral Drainage Layer and the LLDL of SDF closure cap) is evaluated differently. Water-flux driven clay accumulates in the lower drainage layer from the bottom up. The hydraulic conductivity of the clay-filled portion of the Upper Lateral Drainage Layer is reduced from 5.0 x 10^{-2} cm/s to that of the overlying Middle Backfill Layer, 4.1 x 10^{-5} cm/s. The hydraulic conductivity of the upper, non-clay-filled portion of the drainage layer remains at 5.0 x 10^{-2} cm/s. The thickness of the clay-filled portion increases with time, while the thickness of the non-filled portion decreases with time, resulting in an overall decrease in hydraulic conductivity for the drainage layer. The hydraulic conductivity of the backfill is assumed not to change, since its thickness is significantly greater than that of the drainage layer. The different concepts lead to noticeable differences in the saturated hydraulic conductivity values over time, as seen in Table 57 in WSRC-STI-2007-00184 and Table 39 in WSRC-STI-2008-00244. To evaluate the SDF cover performance, the NRC staff needs to understand the possible effect of an F-Tank Farm type conceptual model on projected SDF cover performance since it may be a viable alternative conceptual model for the SDF closure cap and have the potential to significantly affect performance. Alternatively, the DOE could justify why the conceptual model that the DOE used for the F-Tank Farm cover is not applicable to the SDF.

Section 5.4 in WSRC-STI-2008-00244 discusses the HELP SDF closure cap model input values from the topsoil down to the Foundation Layer (e.g., the saturated hydraulic conductivity for the Foundation Layer was given as 1 x 10^{-6} cm/s). Appendixes G and J in WSRC-STI-2008-00244 provide conflicting values as to the assigned saturated hydraulic conductivity of the Lower

Backfill Layer used in the HELP SDF closure cap model (1 x 10^{-3} cm/s and 4.1 x 10^{-5} cm/s, respectively). Additional SDF documents support either one value or the other for the Lower Backfill Layer. Table 15 in WSRC-STI-2008-00244 and Table 4.2-11 in the 2009 SDF PA both gave 1 x 10^{-3} cm/s as the hydraulic conductivity value used, while numerical flow and transport simulations for the SDF discussed in SRNL-STI-2009-00115 (Figures 59-61) show that the 4.1 x 10^{-5} cm/s value was used as the vertical saturated hydraulic conductivity for the Lower Backfill Layer for the PORFLOW calculations. Thus, there is a relatively large discrepancy as to which vertical saturated hydraulic conductivity value is part of the conceptual closure cap design, either 1 x 10^{-3} cm/s or 4.1 x 10^{-5} cm/s.

Section 5.4 from WSRC-STI-2007-00184 discusses the HELP F-Tank Farm closure cap model input values; however, unlike WSRC-STI-2008-00244, WSRC-STI-2007-00184 did include a subsection on the HELP model input values used for the Lower Backfill Layer. Section 5.4.7 stated that 1 x 10^{-3} cm/s was used as the saturated hydraulic conductivity for the Lower Backfill Layer while 1 x 10^{-6} cm/s was used for the Foundation Layer. Appendixes G and J in WSRC-STI-2007-00184 confirmed these values as the HELP input values used in the F-Tank Farm model. If the value used is the HELP SDF closure cap model is the same value used in the HELP F-Tank Farm closure cap model (i.e., a value comparable to that of sand or silty sand), then it would be necessary to identify the future source of the coarser-grained material that would be required to produce the sand or silty sand backfill to provide assurance that the cover can be constructed as designed. If SRNL-STI-2009-00115 is correct and the actual Lower Backfill Layer value used in HELP and PORFLOW for SDF modeling is 4.1 x 10^{-5} cm/s, then an explanation of why the parameter value used for the engineered cover at the F-Tank and the H-Tank Farms is so much higher than the hydraulic conductivity value for the SDF cover given that the designs and locations are so similar would provide additional risk insights.

The conceptual model for drainage layer plugging was discussed in the NRC staff technical review of the performance of the HDPE layer, HDPE/GCL composite layer, and the LLDL (ADAMS Accession No. ML17081A187). For example, the DOE technical basis for the accumulation of clay particles on the bottom of a lateral drainage layer relies on reference from the study of soils. It is not clear to the NRC staff if the accumulation of clays in the B Horizon can be used by the DOE as an analogue for the layers within the engineered surface cover because the references describe the pedogenic process that is the process of soil formation in its natural environment. In addition, the deposition of clay particles may not occur if the water is not tranquil and the velocity of the water flowing laterally in a drainage layer is not slow enough. Alternative conceptual models may also be plausible, such as preferential flow through the soils allowing an uneven deposition of colloids to occur in the sand drain layer and reducing the overall equivalent hydraulic conductivity of the sand. These technical discussions, which focused on the LLDL, may also be applicable and relevant to the Upper Lateral Drainage Layer.

Section 4.4.12 in WSRC-STI-2008-00244 describes the Upper Backfill Layer. The materials and placement method for the upper backfill is essentially identical to that of the middle backfill. The 2.5-ft [0.76 m] thick clayey sand layer will be compacted to achieve an initial saturated hydraulic conductivity of 4.1 x 10^{-5} cm/s. This initial value of the compacted layer is to remain constant for 10,000 years although only 6 in [15 cm] of topsoil lay above the upper backfill and numerous roots from pine tree are assumed to be growing through it. NUREG/CR-7028 (ADAMS Accession No. ML12005A110) and other studies have shown that compacted soil materials used in cover materials at the sites studied did not retain “as built” properties over periods of regulatory interest. The properties of these materials change to values more typical of surrounding soils within 5 to 10 years after installation. The studies indicated that changes in low permeable cover soils can be rapid and can result in an increase to the saturated hydraulic conductivity by three to four orders of magnitude. If sensitivity modeling results show that an Upper Backfill Layer with hydraulic conductivity values adjusted to more closely resemble the values of the surrounding soils prompt significant changes to the modeling results, then additional technical justification is needed to support values representing continual compaction.

The DOE Flow Cases F01, F04, F05, F14, and F30 are described in Section 5.6.7.3 of the FY14 Special Analysis Document. Flow Case F14 is the only flow case to represent a higher infiltration rate of 31.62 cm/yr [12.45 in/yr] and therefore a higher LLDL degradation rate. Flow Case F14 also represents nominal degradation of cementitious materials, as does Flow Case F01, and initially high saturated hydraulic conductivity of saltstone, as does Flow Case F05. While the peak doses for Flow Case F05 increases from 21 to 23 mrem/yr between the 10,000 to 20,000-year timespan, the peak doses for Flow Case F01 actually goes down during the same timespan from 12.5 to 7.3 mrem/yr. Flow Case F14 differs from both of these flow cases in that the peak dose between 10,000 and 20,000 years more than doubles from the 10,000-year peak dose (i.e., the peak dose climbs from 24 mrem/yr to 59 mrem/yr (Figure 5.6.7-5 in the FY 2014 Special Analysis Document)). Table 5.6.7-4 shows that Flow Case F14 also has the highest peak doses for each of the three time periods given: 0 - 1,000 years, 0 - 10,000 years, and 10,000 - 20,000 years. Thus, although further sensitivity analyses would be required, these flow case sensitivity analysis results seems to indicate the importance of infiltration rates through saltstone.

The importance of the infiltration rate on overall performance are shown in the results of recent research (the DOE document SREL Doc. No. R-16-0003) on the chemical retention in emplaced saltstone of Tc-99 and I-129 at early times. The objective of this research was to evaluate contaminant leaching using test methods that accommodate intact saltstone monoliths that better represent the initial physical and chemical state of saltstone within the disposal structures. These results showed that the rate of release of radionuclides (i.e., moles or grams per year) directly impacts dose and the results showed that Tc-99 and I-129 releases occur earlier than what the DOE assumed in the FY14 Special Analysis Document. That rate of release is controlled by the solubility and sorption of radionuclides as well as the flow through the system. Before approximately 1,000 years in the PORFLOW near-field model, flow through the SDF was projected to be largely controlled by the closure cap. Thus, modeled flow through the SDF system and, therefore, the dose is, in part, controlled by the closure cap. A low solubility limit or high sorption coefficient can mitigate the effects of a high flow rate by slowing down radionuclide release relative to water flow. However, the rate of release of Tc-99 and I-129 as seen in the DOE's research results increases the importance of physical barriers to minimize flow.

Although the DOE's research is ongoing, the concentration of Tc-99 in the early pore volume flushes from actual saltstone core samples documented in SREL Doc. No. R-16-0003 (i.e., peak concentrations of 5×10^{-7} mol/L) exceeds the concentrations assumed in the Evaluation Case (i.e., 1×10^{-8} mol/L) and a technetium solubility sensitivity study that evaluated the dose impact of a Tc-99 solubility of 1×10^{-7} mol/L. Furthermore, it is not clear from this preliminary study that the solubility limit of Tc-99 was achieved. A longer residence time, which is expected to be more consistent with projected field conditions at early times, could result in higher Tc-99 concentrations. Recent sorption research on I-129 from actual saltstone core samples also indicates that the release of I-129 may be more rapid than assumed in the FY14 Special Analysis Model, and the peak concentration in the groundwater at the receptor site may occur earlier than projected in the FY 2014 Special Analysis Document. From that research, the DOE concluded that the I-129 K_d for saltstone is <1 mL/g and potentially 0 mL/g. As NRC staff discussed in a TRR on iodine sorption coefficients (see ADAMS Accession No. ML16342C575), those values are lower than what was assumed in the FY14 Special Analysis Document. Because the peak groundwater concentration of these risk significant radionuclides may occur earlier than projected in the FY 2014 Special Analysis Document, the barriers that limit flow early in the performance period are more risk significant than previously assumed.

Based on intermediate results produced by DOE from the PORFLOW near-field model, the NRC staff determined that the closure cap can significantly delay and reduce the magnitude of the dose from those radionuclides at early times. Because a risk-significant fraction of these radionuclides can be released in the first pore volume flush through the saltstone grout, the amount of time it takes for the first pore volume to be released is important. For example, it appears that one cumulative pore volume is not released from a 375-ft diameter disposal structures, which controls the I-129 peak, until approximately year 2,600. If closure cap assumptions are determined to be optimistic and greater flow through the closure cap could be realized earlier than projected, then the release of radionuclides in the first pore volume could occur in a shorter amount of time, increasing the annual release rate, and the dose at these early times could be much greater.

Monitoring Factor 2.02 Including Intruder Barrier Stability and Minimizing Erosion:

"Erosion of the Soil above the Erosion Barrier" is a subsection within Appendix I of WSRC-STI-2008-00244 and documents the method by which the erosion rates of the Topsoil Layer and the Upper Backfill Layer were calculated for a 10,000-year period. The erosion rates of the topsoil and backfill on top of the Erosion Barrier are important because changes in the soil thickness can change the evapotranspiration, which, in turn, can change the infiltration rate. In addition, a thinning of the soil thickness can change the size of the root diameter and the number of roots at the Erosion Barrier and therefore the overall root disruption of this rock layer. The projected erosion rates of these layers were determined utilizing the Universal Soil Loss Equation (USLE) (Goldman et al., 1986).

The Universal Soil Loss Equation is expressed as: $A = R \times K \times LS \times C \times P$, where
A = soil loss (tons/acre/year);
R = rainfall erosion index (100 ft·ton/acre per in/hr);
K = soil erodability factor, tons/acre per unit of R;
LS = slope length and steepness factor, dimensionless;
C = vegetative cover factor, dimensionless;
P = erosion control practice factor, dimensionless.

The Revised Universal Soil Loss Equation (RUSLE) is a revised and updated version of the original USLE used in the Agricultural Handbooks by the U.S. Department of Agriculture on the subject. It is the third version of the USLE, and it is described in Agriculture Handbook No. 703 (Renard, et al., 1997). The RUSLE retained the equation structure of the USLE, but each factor was either updated with recent data, or new relationships were derived based on modern erosion theory and data. Some of the factors that make up the soil loss equation have changed. For example, the rainfall erosion index, or the R value, used in WSRC-STI-2008-00244 was obtained from Figure 5.2 of Goldman et al. (1986), and an R value of 260 100 ft·ton/acre per in/hr [2.69 $m \cdot kg/m^2$ per cm/hr] was utilized. Renard, et al. (1997) also included an updated isoerodent map of the eastern United States. Based on this map, the R value should be updated to a value somewhere between 290 and 300.

Based on Appendix I from WSRC-STI-2008-00244, the vegetative cover factor, or the C factor, used for the soil erosion calculations was taken as that of a natural successional forest from

Horton and Wilhite (1978) with a value of 0.001 (a value of 0.004 was used for Bahia grass). The C factor values found in references can differ by several orders of magnitude. For example, Goldman et al. (1986) also discusses C factors, or the “cover management factor,” and their Table 5.6 encompasses several C factor values for different types of vegetative covers including undisturbed native vegetation with a value of 0.01, the lowest value in this table, however an order of magnitude higher than Horton and Wilhite (1978). Since this factor has the potential to significantly change the magnitude of the projected soil loss, a sound technical justification should be provided for the C factor chosen by DOE. For example, the source referenced for the natural successional forest C factor used in Horton and Wilhite (1978) was given as Wischmeier (1975). In the discussion over the C factor for woodland, Wischmeier (1975) discussed possible combinations of different percentages for forest covered by tree canopy, forest litter or duff, and undergrowth that grows under canopy openings not protected by forest litter. The lowest C factor listed in Table 3 in Wischmeier (1975) (i.e., 0.001) represents a well-stocked woodland with 100 percent forest litter and managed undergrowth. Managed is defined in the same Table 3 as areas where grazing and fires are controlled. To assess long-term performance of a disposal system at a site in the future, it is generally assumed that institutional controls will end after 100 years. Assuming this to be the case, managed undergrowth would no longer be an accurate description for the site after 100 years since fire prevention management would cease and periodic, if irregular, fires could not be excluded from burning the undergrowth and forest litter and young trees. Values for unmanaged undergrowth in Table 3 area given as 0.003 to 0.011 (average is 0.007). More recent publications may provide additional information as to the correct range of C factors.

To demonstrate the sensitivity of the soil loss equation to relatively small changes to the parameter values, alternative NRC staff calculation results are shown here for topsoil with a pine forest where the R value of 260 is replaced with 295 and the C value of 0.001 with 0.007 while other parameter values are maintained as shown on page 216 in WSRC-STI-2008-00244.

A = 295 x 0.28 x 0.29 x 0.007 x 1 = 0.17 tons/acre/year

Based on the equation on page 217 in WSRC-STI-2008-00244:

Soil loss rate (alternative calculation) = (0.17 x 2000 x 12)/(43560 x 104) = 9 x 10^{-4} in/yr

For comparison, WSRC-STI-2008-00244 has a loss of 1.1 x 10^{-4} in/yr (original calculation).

Wilkinson and McElroy (2007) include a figure showing the estimates of average natural erosion rates and give a mean rate of denudation for the entire area of the contiguous United States as approximately 8.3 x 10^{-4} in/yr. The State of South Carolina has an estimated average natural erosion rate of less than 5.9 x 10^{-4} in/yr. For a more direct comparison, Horton and Wilhite (1978) calculated the estimated annual soil loss at the SRS for an area with a natural successional forest-type vegetation and arrived at a rate of 2.8 x 10^{-4} in/yr, or almost three times the rate of 1.1 x 10^{-4} in/yr calculated in WSRC-STI-2008-00244 for topsoil with a pine forest vegetative cover.

Further calculations with the revised C factor and R values were performed using the equations from page 218 in WSRC-STI-2008-00244. Calculations for topsoil with an undisturbed forest resulted in the projected complete loss of the 6 in [15 cm] thick Topsoil Layer after 6978 years. An additional 1.9 in [4.7 cm] of backfill are projected to be eroded by 10,000 years so that the Upper Backfill Layer has a remaining thickness of 28.1 in [71.5 cm].

The alternative NRC staff calculations resulted in a total erosional loss of 7.9 in [20 cm]. This compares to the 10,000-yr erosional loss of 1.26 in [3.2 cm] seen in WSRC-STI-2008-00244. The difference in the results based on relatively small changes to two of the parameters demonstrates that good technical bases for the significant parameters are needed.

As previously discussed, the new 375-ft diameter disposal structure design as presented in the FY14 Special Analysis Document could require changing the closure cap design in some way with the consequence that a majority of calculation results as documented in WSRC-STI-2008-00244 would need to be reanalyzed and reassessed. That reanalysis would include the erosion calculations as documented in Appendix A of WSRC-STI-2008-00244. For future closure cap designs, slope length, slope of the closure cap surface, slope of the side slope, height of the side slope, or the number of benches may need to be changed to accommodate the 375-ft diameter disposal structure design. Therefore, the size and thickness of the erosion barrier riprap, size of the side slope riprap, size of the riprap for the side slope toe, and actual velocity for runoff on a 1.5 percent vegetative soil cover may need to be reevaluated.

The SDF and the future closure caps will be built on the current Z Area. The surrounding land consisting of unconsolidated soils and sediment sand will support any future surface cover over the SDF (i.e., act as a base or a foundation). Severe erosion and gully growth in the land surrounding the Z Area in the future could have the potential to disturb the closure cap and possibly effect the isolation of the saltstone. Due to the importance of controlling erosion in the area surrounding the SDF, the NRC staff recommends clarifying that areas adjacent to the future closure cap should also be part of the NRC monitoring at the SDF. Areas of interest would include those areas that had previously been part of OOVs by NRC staff (i.e., land northeast of the asphalted service road and between the Z Area and portions of the Upper Three Runs and McQueen Branch (see Figure 6)), especially those areas where the topography has a steeper incline. Consequently, this TRR recommends revising the title and description of MF 2.02 to read as follows: Erosion Control of the SDF Engineered Surface Cover and Adjacent Area.

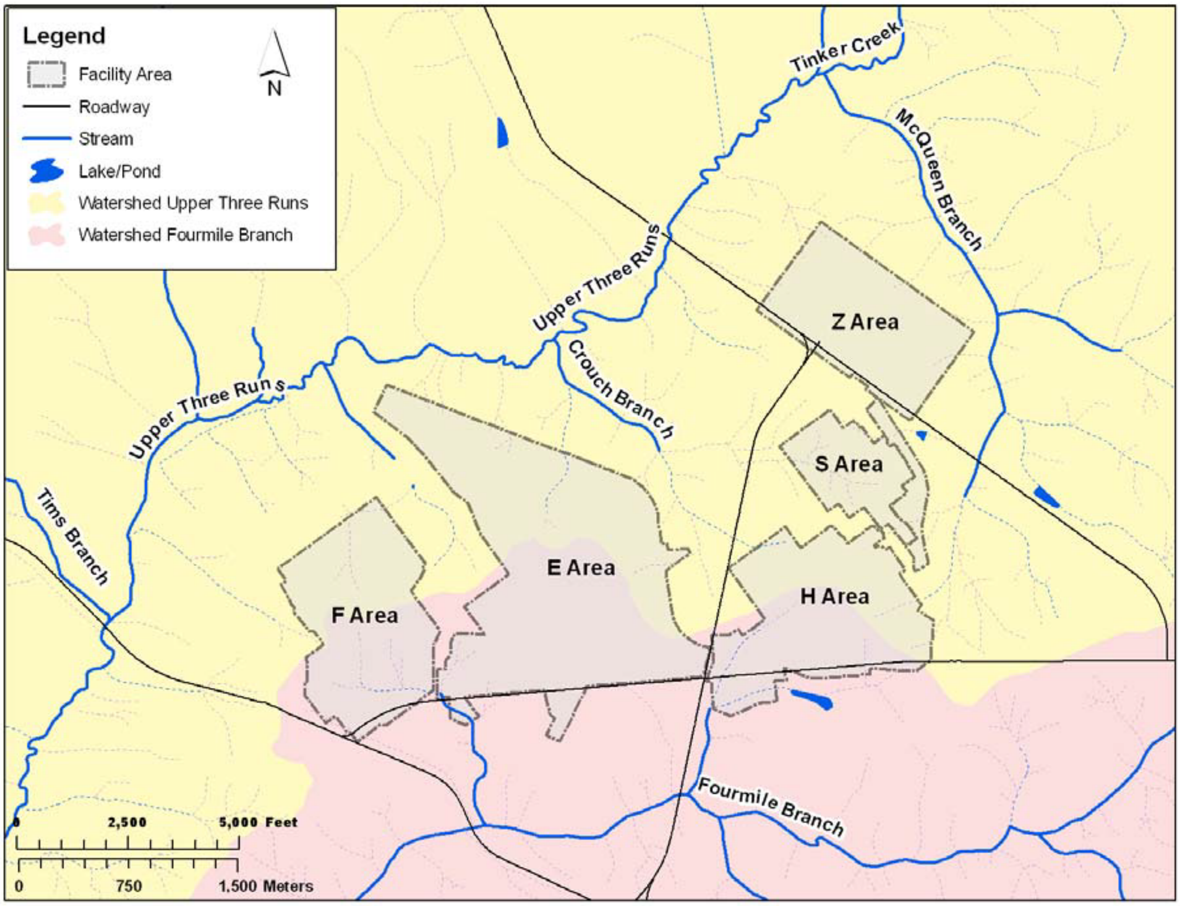

Figure 6: SRS near the Z Area (Figure 3.1-4 in the 2009 SDF PA)

Future Scenario Uncertainty as It Relates to Infiltration and Erosion

The staff reviewed the response to RAI Question PAM-4 (SRR-CWDA-2016-00004). Although the RAI question gave an example of how an alternative climate scenario could change the current groundwater flow system, the DOE responded that an increase or decrease in rainfall would not alter hydrologic flow patterns. Recent measurements at wells in the Z Area, however, potentially show how groundwater flow systems can change due to variations in conditions. The history of SDS 4 has included release of contaminants into the surrounding soils. Well ZBG 4 is located next to the disposal structure while Well ZBG 2 was located a little more than 100 m [328 ft] down gradient. ZBG 4 is located below the Tan Clay Confining Zone (TCCZ) while the open screen interval for ZGB 2 was located above the TCCZ. Using a concentration of 10 pCi/L of the contaminant Tc-99 as an example, Tc-99 was detected above the 10 pCi/L concentration level at ZBG 2 nine years before ZBG 4 (Figure 7 and Table 2 respectively, SRNS-TR-2016-00312), although ZBG 4 is approximately 100 m [328 ft] closer to the possible source (i.e., near SDS 4) than ZBG 2. In SRNS-RP-2015-00902 and also in the NRC OOV report from February 2015 (ADAMS Accession No. ML15041A562), DOE described a conceptual model where water from near SDS 4 would flow along the top of the TCCZ and into ZBG 2. That is, given sufficient recharge to raise the water table above the TCCZ, DOE proposed that water will flow in a predominately lateral direction, possibly flowing in troughs on the surface of the TCCZ (Figure 20, SRNS-RP-2015-00902). On the other hand, if the water table is below the TCCZ, recharge water follows a downward, yet slower path, through the TCCZ. If this conceptual model is correct, this is an example of contaminant transport direction changing paths and possibly changing the point of exposure.

RAI Question PAM-4 also referred to four different flow cases evaluated which included a range of infiltration rates that reflected potential changes in climate and rainfall. Included in the sensitivity analysis, Flow Case F14 was described as most pessimistic and was represented with high infiltration, nominal degradation, and initially high saturated hydraulic conductivity. That case produced a projected peak dose within 10,000 years of 24.1 mrem/yr. In their response to RAI Question PAM-4, DOE described the flow case as representing extreme conditions and the infiltration rate as a maximum infiltration rate. These descriptions could be somewhat misleading since the current average infiltration rate in this area is considered to be 14.8 in/yr [37.6 cm/yr] (WSRC-STI-2008-00244) while the maximum modeled infiltration rate used for the closure cap at 10,000 years was 12.45 in/yr [31.62 cm/yr]. This value is less than 2 in/yr [5 cm/yr] more than the average infiltration rate through the closure cap of 10.6 in/yr [26.9 cm/yr] used by the HELP model. The maximum modeled infiltration rate of 12.45 in/yr was obtained by DOE with model precipitation rates ranging between 46.7 in/yr [119 cm/yr] and 68.6 in/yr [175 cm/yr], which cannot be described as extreme compared to the 1964 annual precipitation of 71.74 in [182.2 cm/yr] at the 200-F weather station. No analysis has been presented by DOE excluding the possibility of precipitation rates greater than 68.6 in/yr or 71.74 in/yr in the next 1,000 or 10,000 years. Sensitivity analyses based on plausible alternative conceptual models developed from features and processes that have changed over time (e.g., variations in temperature and rainfall cause the vegetation on the closure cap to change thereby influencing infiltration and erosion) could help to determine the significance of this RAI question on performance.

Although there is no evidence of significant erosion in the area surrounding the SDF, only current conditions representative of the present and the near past could be observed during the 2017 OOV. Additional DOE analyses could reduce scenario and conceptual model uncertainty. DOE had previously developed an initial list of features, events, and processes (FEPs) for the SDF performance assessment and screened those FEPs to obtain the final screening results (SRR-CWDA-2012-00011). However, the final FEP results were never used to investigate if plausible, alternative scenarios of the future could be developed from the remaining FEPs. Different potential future changes to vegetation, infiltration, and erosion could impact future facility performance differently. The concern raised by the NRC in RAI Question PAM-4 as it pertains to future erosion rates for land surrounding the SDF and the future closure cap under different, yet plausible, climate states remains. That concern is closely related to the uncertainty associated with the future evolution of the SDF, or scenario uncertainty. If different evolutions of the SDF are shown to be plausible, then evaluating multiple scenarios may provide an appropriately comprehensive technical description of the estimated performance in the future. The most plausible future scenario of a disposal site, also called the central scenario, usually will not include disruptive events (e.g., earthquake, flood) since the disposal usually will not have been selected at a site where this is probable. Alternative scenarios that are less likely but still plausible descriptions of future evolutions of the disposal site can and sometimes do include disruptive events. For clarification purposes and to distinguish more clearly between model uncertainty and future scenario uncertainty, this TRR recommends creating a separate MF on scenario uncertainty. MF 10.02 (Defensibility of Conceptual Models) on model uncertainty will not be revised. This TRR recommends that MF 10.14 (Scenario Development and Defensibility) be added to the SDF Monitoring Plan under performance objectives §61.41 and §61.42.

NRC Conclusions

In the NRC 2012 SDF TER, the NRC staff concluded that although the closure cap design will not be made final until closer to the time of SDF closure, verification that certain designed features can be implemented as designed is needed in advance of SDF closure to allow sufficient time to change the design, or the assumptions regarding long-term erosion and infiltration, if necessary. Several concerns expressed in the 2012 SDF TER and/or the 2013 SDF Monitoring Plan are reiterated below because they still exist.

- A preliminary evaluation of rock sources should be conducted to provide confidence that an acceptable rock source is available.

- Pore-pressure build-up in the overlying closure cap layers could affect cover stability, vegetation, hydraulic performance of cover materials, and erosion. If an analysis containing more detailed simulations determined that the buildup of hydraulic head is realistic, an explicit evaluation of the physical stability of cover materials under this condition would be needed.

- More model support is needed for the long-term infiltration-limiting performance of the closure cap due to the importance of infiltration to system performance.

- An evaluation of the cumulative effects from precipitation events over long time periods with respect to gully formation was needed to support predictions of long-term performance of the topsoil and vegetative layers. In addition, the stability of a degraded vegetative cover should be evaluated because the Bahia grass, bamboo, or pine forest could be degraded by fire or extended drought, which could adversely affect the ability of the vegetative and topsoil layers to resist erosion.

In this TRR, the NRC staff identified new concerns related to design features, or assumptions related to closure cap or cover design.

- The 375-ft [114-m] diameter disposal structure design as presented in the FY 2014 Special Analysis Document may require changing the closure cap design in some way. Such changes would require that a majority of infiltration calculations as documented in WSRC-STI-2008-00244 would need to be reanalyzed and reassessed. That reanalysis would include the erosion calculations as documented in Appendix A of WSRC-STI-2008-00244.

- NUREG/CR-7028 and other studies have shown that compacted soil materials used in cover materials at the sites studied did not retain “as built” properties over periods of regulatory interest, which means that additional justification may be needed to support values representing continual compaction.

In this TRR, the NRC staff reiterated previous and new staff concerns related to the uncertainty of performance due to different, yet plausible, future scenarios of the SDF.

- During the 2016 OOV, the NRC and DOE discussed additional information that might be included in the next revision to the SDF PA, including infiltration projections that reflect the uncertainty in future climate states.

- During the 2017 OOV, only current conditions representative of the present and the near past could be observed. Additional analyses to reduce scenario and conceptual model uncertainty could provide increased confidence of performance and allay concerns pertaining to future erosion rates for land surrounding the SDF and the future closure cap under different, yet plausible, climate states.

- For clarification and to distinguish more clearly between model uncertainty and future scenario uncertainty, this TRR recommends creating a separate monitoring factor on scenario uncertainty as MF 10.14 (Scenario Development and Defensibility) under performance objectives §61.41 and §61.42.

In this TRR, the NRC staff identified concerns related to the HELP code and uncertainty pertaining to its parameters.

- The DOE appears to be relying on a code that is less conservative than others and, although no computer code will be perfect for what is needed by the DOE, some computer codes will be better suited than others – the HELP code has numerous critics, as documented in the 2007 National Research Council, "Assessment of Performance of Engineered Barriers."

- A HELP input entry value for vegetation may be a possible cause for the relatively high projected runoff value for the last half of the 10,000 time period. The "Good stand of grass" vegetation type chosen by the DOE may be optimistic if a pine forest is expected, and a sensitivity analyses would help to determine if vegetation type has a significant effect on modeled runoff and infiltration.

- The calculated combined saturated hydraulic conductivity of the combined HDPE and GCL layers is dependent on the layer with the lower hydraulic conductivity. The input property values of the HDPE geomembrane, and not the GCL, are the determining factors controlling the infiltration rate through the combined HDPE/GCL composite layer.

- The hydraulic conductivity of the GCL layer is changed (from 5.0×10^{-8} cm/s) after a few hundred years, together with the HDPE, to a combined hydraulic conductivity value for the HDPE/GCL composite layer (to 8.7×10^{-13} cm/s) – it is unclear if a 0.2 in [5 mm] bentonite layer protected by geotextile would survive intact as a recognizable layer for 10,000 years. Sensitivity analyses would be helpful to recognize the significance of such assumptions and changes.

- There is a discrepancy between different references as to which value of saturated hydraulic conductivity is used by the DOE for the Lower Backfill Layer in the SDF conceptual closure cap design.

- The analysis of the closure cap for the F-Tank Farm (WSRC-STI-2007-00184) presented an alternative degradation conceptual model of the upper lateral drainage performance as compared to the conceptual model considered for the SDF. The F-Tank Farm conceptual model may be a viable alternative conceptual model for the SDF closure cap and have the potential to significantly affect performance.

In this TRR, the rate of water infiltrating through the wasteform was determined to be significant to performance.

- The rate of release of Tc-99 and I-129 as seen in DOE research results increases the importance of physical barriers to minimize flow and indicates that the closure cap may be more risk significant than previously assumed. Although the research is ongoing, the concentration of Tc-99 in the early pore volume flushes from actual saltstone core samples exceeds the concentrations assumed in the Evaluation Case and a technetium solubility sensitivity study that evaluated the dose impact of a Tc-99 solubility. Recent sorption research on I-129 from actual saltstone core samples also indicates that the release of I-129 may be more risk significant.

- Due to the importance of infiltration rates through the closure cap, this TRR recommends changing the priority of MF 2.01 from low priority to medium priority.

In this TRR the NRC staff identified concerns related to slumping of the closure cap and silting-in of cover layers were identified.

- Previously, the NRC staff expressed concern that subflow from the closure cap drainage layer flowing through the side slope riprap could significantly increase the water content of the backfill beneath the side slope and lead to slumping (ADAMS Accession No. ML121170309). Because saturated conditions at the surface would increase concerns of geotechnical stability, an understanding of moisture content for each layer over time is needed. If saturated conditions exist, an evaluation of the physical stability of the cover materials also would be needed.

- Compared to an erosion barrier filled with sandy soil, an erosion barrier filled with CLSM would increase the chance of lateral flow occurring on top of the erosion barrier thereby potentially decreasing the stability of the closure cap. Concerns would include the stability of the outer edges of the upper backfill layer as the backfill material may be carried out by the lateral flow into the side slopes. In addition, higher moisture contents or saturation levels may deter growth of the loblolly pine and promote vegetation more acclimated to moister soils.

- The NRC staff conclusions in a previous TRR related to the LLDL (ADAMS Accession No. ML17081A187) are also relevant to the Upper Lateral Drainage Layer.

In this TRR, the NRC staff identified concerns related to the soil loss equation as.

- The DOE R value, or the rainfall erosion index, should be updated based on the newer RUSLE equation.

- The DOE value for unmanaged undergrowth should be used to obtain the C factor, or vegetative cover factor, and more recent publications may provide additional information as to an appropriate range of values.

- Potential differences in 10,000-year soil-loss results (e.g., 1.3 in vs. 7.9 in [3.3 cm vs. 20 cm]) based on calculations using relatively small parameter value differences means that the appropriate technical bases for significant parameters are needed.

- For clarification due to the importance of controlling erosion in the area surrounding the SDF, this TRR recommends changing MF 2.02 so that the area adjacent to the future SDF closure cap will be monitored under MF 2.02 under performance objectives §61.41 and §61.42.

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