Third Set of Request for Additional Information Questions
For the U.S. Nuclear Regulatory Commission
Technical Review Reports Regarding the
U.S. Department of Energy 2020 Savannah River Site
Saltstone Disposal Facility Performance Assessment

INTRODUCTION:

The U.S. Nuclear Regulatory Commission (NRC) staff identified the following request for additional information (RAI) questions while drafting technical review reports (TRRs) regarding the U.S. Department of Energy (DOE) 2020 Savannah River Site (SRS) Saltstone Disposal Facility (SDF) Performance Assessment (PA) (NRC's Agencywide Documents Accessand Management System [ADAMS] under Package Accession No. Main Library (ML) ML20190A055).

The staff has organized the review into 14 technical topics: (1) performance assessment methods; (2) saltstone performance; (3) composite barriers and drainage layers; (4) infiltration and erosion control; (5) disposal structure performance; (6) far-field flow and transport; (7) inadvertent human intruder; (8) biosphere; (9) inventory; (10) site stability; (11) Selection of Features, Events, and Processes; (12) Conceptual Models and Future scenario uncertainty; (13) near-field flow and transport; and (14) radionuclide release. Not all technical topics will be in each set of RAI questions.

Each NRC RAI question will be identified by its technical topic and the number of the RAI questions in that technical topic. Each RAI question contains the requested information, a basis, and a path forward. The path forward represents one possible approach to a resolution of the RAI question. The NRC staff understands that there may be more than one approach to adequately address the technical issue raised in each RAI question. The adequacy of the DOE responses to some RAI questions may depend on the nature of the resolution of other RAI questions.

This third set of NRC RAI questions for the TRRs is related to the following four technical topics: near-field flow and transport; composite barriers and drainage layers; radionuclide release; and sensitivity and uncertainty analyses. In addition, the NRC staff has some clarifying comments (CCs) about the DOE 2020 SDF PA.

RAI Questions for the Technical Topic of Near-Field Flow and Transport (NFF&T):

NFF&T-1

The NRC staff needs additional information regarding the initial hydraulic conductivity of saltstone grout.

Basis

In Section 2.2 in the DOE document SRR-CWDA-2021-00056 (ADAMS Accession No. ML21217A081), the DOE described the recommended distribution of the initial saturated hydraulic conductivity of saltstone. The DOE based that distribution on a log-normal representation of 509 measurements of saltstone grout. Those values included hydraulic conductivity measurements that were collected during and after the initial pore volume flush.

A significant decrease in hydraulic conductivity was shown in Figure 13 in the DOE document SRR-CWDA-2020-00008 (ADAMS Accession No. ML21232A636) for several samples with the dynamic leach method (DLM). The DOE described that the mechanism associated with that phenomenon of hydraulic conductivity reduction within the initial pore volume had not been determined. That phenomenon was also seen in the DLM results shown in Figure 2.2-1 in the DOE document SRR-CWDA-2021-00056. The NRC staff agrees that the mechanism of that reduction is not clear and that the following two hypotheses, which were presented in Section 3.3 in the DOE document SREL DOC No. R-15-0003 (ADAMS Accession No. ML16013A355), are plausible: (1) formation of secondary precipitates within the saltstone matrix, and (2) suspension and transport of colloidal materials that clog pore constrictions.

If flow through the grout is resulting in mineralogical changes or changes in flow dynamics, then the initially higher saturated hydraulic conductivity value may be representative of the initial saturated hydraulic conductivity of field-emplaced saltstone. Because the peak dose is strongly influenced by the initial/early pore volume flushes, the NRC staff is concerned that representing all of the hydraulic conductivity measurements in the distribution for the initial hydraulic conductivity may underestimate initial contaminant release rates. Separate modeling of the hydraulic conductivity of saltstone grout during the initial pore volume flush may be important to understanding initial contaminant release rates.

Path Forward
Provide justification for why the initial hydraulic conductivity of saltstone is not risk-significant. Alternatively, discuss any information or research that may be developed to determine if the observed initially high hydraulic conductivity of saltstone is an experimental artifact.

NFF&T-2
The NRC staff needs additional information regarding the material properties and mineralogy of the cement-free saltstone grout.

Basis
In Table 2.3-6 in the DOE 2020 SDF Special Analysis Document, SRR-CWDA-2020-00064 (ADAMS Accession No. ML21232A639), the DOE provided the material properties for cement-free saltstone grout. Those material properties were based on an analysis of the cement-free design mix and a comparison with the results of a similar analysis for typical saltstone grout, as described by the DOE in Table 21 in the DOE document, SRR-CWDA-2020-00040 (ADAMS Accession No. ML21160A064).

Because of the significant change in the saltstone design mix (i.e., eliminating ordinary Portland cement) and the complexity of cementitious material reactions, there is uncertainty in relying on analytical approaches for determining material properties. The assumed saltstone porosity and density influence flow and contaminant transport. The risk-significance of those material properties to dose is not clear to the NRC staff.

In addition, the removal of ordinary Portland cement from the saltstone grout formulation could affect the mineralogy of saltstone. Consequently, differences in mineralogy could result in differences in solubility between typical saltstone and cement-free saltstone. That could impact the decalcification and contaminant release rates.

Path Forward
Provide a laboratory analysis of the material properties of cement-free saltstone grout, including particle density, dry bulk density, and porosity. Alternatively, provide a sensitivity analysis

demonstrating that those material properties of saltstone grout are not risk-significant. In addition, provide an analysis (e.g., X-ray diffraction) of cement-free saltstone grout to determine the mineralogy.

NFF&T-3
The NRC staff needs additional information regarding the calcium concentration in cement-free saltstone grout.

Basis
In Table 2.3-7 in the DOE 2020 SDF Special Analysis Document, SRR-CWDA-2020-00064, the DOE provided the chemical reaction capacities for cement-free saltstone. For those reaction capacities, the DOE relied on a normative analysis to estimate the calcium and aluminum concentrations in the cement-free grout. In that analysis, the DOE calculated that the cement-free formulation had a higher calcium concentration than typical saltstone, as shown in Table 2.3-7. However, Table 2 in the DOE document SRR-CWDA-2020-00066 (ADAMS Accession No. ML21217A083) showed that the cement had a higher calcium content than the slag and fly ash. Accordingly, it is not clear to the NRC staff how the cement-free formulation (i.e., 60 weight percent (wt%) slag and 40 wt% fly ash) had more calcium than the typical saltstone (i.e., 45 wt% slag, 45 wt% fly ash, 10 wt% cement).

In Section 4.4.2.5 in the DOE 2020 SDF PA, the DOE provided the calculation for the assumed time to complete degradation based on decalcification, which was based in part on the assumed calcium content of saltstone. In Table 2.3-10 in the DOE 2020 SDF Special Analysis Document the DOE provided the assumed times for complete degradation of typical and cement-free saltstone. Using the updated normative analysis for cement-free saltstone with a higher calcium concentration, the DOE calculated a significantly longer time to completed degradation. Because of that risk-significance of the calcium concentration, the NRC staff needs more information on the chemical composition of cement-free saltstone.

Path Forward
Provide a laboratory analysis of the chemical composition, including calcium concentration, of cement-free saltstone.

NFF&T-4
The NRC staff needs additional information regarding the heat generation observed in the tests of cement-free saltstone.

Basis
On page 30 in the DOE document SRR-CWDA-2020-00008, the notes from an experiment with cement-free saltstone indicated that two of the three buckets showed "… excessive heat and bubbling of the cement-free composition." That DOE document then noted that the experimenter discarded the two bubbling samples after confirmation by a DOE-Contractor representative.

It is not clear to the NRC staff whether the excessive heat and bubbling observed during the bucket-scale test could occur in full-scale disposal structures. In addition, it is not clear to the NRC staff whether the cured properties of grout that underwent excessive heat generation and bubbling would have different cured temperatures than used in the flow and transport models for the DOE 2020 SDF PA.

Path Forward
Provide information about whether the two bubbling samples observed in the experiment are representative of field-emplaced saltstone. Indicate what, if any, effects the observations could have on the properties of field-emplaced saltstone.

NFF&T-5
The NRC staff needs additional information regarding the initial hydraulic conductivity of the cement-free saltstone grout.

Basis
For cement-free grout, Figure 4 in the DOE document SRR-CWDA-2020-00040 showed significantly higher saturated hydraulic conductivity values for samples that were measured according to the American Society for Testing and Materials (ASTM) standard than for samples measured with the DLM. Those samples were cured for a shorter period than many of the samples for which the DOE provided DLM test results. However, for samples of comparable curing duration, the ASTM results were still more than an order of magnitude greater than the DLM results.

Path Forward
Provide longer-term saturated hydraulic conductivity testing using the ASTM method for cement-free grout. Alternatively, provide any additional technical basis for why the ASTM results are not representative of initial conditions.

RAI Questions for the Technical Topic of Composite Barriers and Drainage Layers (CBs&DLs):

The NRC staff adapted most of the information found in the “Basis” of the RAI questions in this section (i.e., CBs&DLs) from a report developed by the Center for Nuclear Waste Regulatory Analyses (CNWRA) (ADAMS Accession No. ML21287A328). Additional details about the CNWRA evaluation of the upper lateral drainage layer (ULDL), the lower lateral drainage layer (LLDL), and the composite barrier layers composed of high-density polyethylene (HDPE)/geosynthetic clay liner (GCL) can be found in that report. Both the composite barriers and drainage layers are features of a cover system for which the DOE has not yet finalized the design. Therefore, for the questions in this section, the NRC staff expects that some specific technical information that relies on the final design might not be available. However, the DOE responses should provide an overview of how the DOE intends to reduce the uncertainties identified in each question.

CBs&DLs-1
The NRC staff needs additional information regarding the DOE plans for reducing the risk-significant uncertainty associated with root penetration of the ULDL, HDPE, and GCL in the closure cap and the resulting reduction of performance due to that degradation.

Basis
The DOE documents SRR-CWDA-2021-00040 and SRR-CWDA-2021-00066 demonstrated the risk-significance of the ULDL and its associated composite barrier to performance. The 2009 SDF PA closure cap model included degradation in the form of plant root penetration through the composite barrier layers. The DOE 2020 SDF PA closure cap model did not include that form of degradation for the reasons in the DOE document, SRRA107772-000009 (ADAMS Accession No. ML18170A244). That document indicated that no root systems were observed

below the composite barrier at any covers evaluated in the NRC document NUREG/CR-7028 (ADAMS Accession No. ML12005A111). The authors of the DOE document SRRA-107772-000009 examined three sites (i.e., Cedar Rapids, Iowa; Omaha, Nebraska; Polson, Montana) with covers less than ten years old. All three of those sites had conventional covers with grasses and no trees growing in the topsoil. The authors of that DOE document excavated sections of the cover (i.e., 2 meters (m) by 2 m [6 feet (ft) by 6 ft]) and examined the sections for root growth.

The SDF area has a humid subtropical climate and receives more precipitation than the three example sites examined in the NRC NUREG/CR-7028. Pine trees (e.g., the loblolly pine) are the dominant flora in the SDF area. Without maintenance, it is very plausible (i.e., reasonably foreseeable) that trees will ultimately colonize the cover after intuitional control ends. Although root penetrations would be unlikely over portions of the cover with the HDPE geomembrane below the rooting depth, based on the DOE 2020 SDF PA surface and ULDL slopes (i.e., 0.03 and 0.04, respectively), roots would potentially reach the geomembrane up to 183 m (600 ft) from the ridgeline with the 3.66-m (12-ft) maximum rooting depth as used in the 2009 DOE SDF PA. Based on the SDF Closure Cap Design Configuration map in Figure 3.2-29 in the DOE 2020 SDF PA, it appears that all SDF disposal structures, except for Saltstone Disposal Structure (SDS) 3A, SDS 3B, SDS 5A, and SDS 5B, would be at least partially within the potential root degradation area.

That DOE document SRRA107772-000009 also indicated that roots will accumulate in regions where water was more plentiful and will not grow toward drier regions where water was more difficult to extract. That is, water will tend to accumulate above the composite barrier while the soil dries below the composite barrier. Although root systems do tend to accumulate in wetter areas, such as the lateral drainage layers above composite barrier layer, that would imply that the root system would find the base of the ULDL adjacent to the HDPE geomembrane especially appealing. Probing root caps along the bottom of the ULDL may penetrate an HDPE geomembrane at heat-affected zones near seams that are covered by an overlapping geomembrane flap. Root growth under such flaps would exert tensile forces on the heat-affected zones. Tree root systems would be expected to penetrate initial defects and enlarge them over extended periods of time. If a root did penetrate the geomembrane, then the environment under a defect would probably not remain dry. Instead, water is likely to soak the area under a defect in this humid location and any expansion of the defect from a root penetration will only increase the water supply and potentially supply additional water for the root system.

The erosion barrier likely will not impede a tree root system from growing through it. The DOE considered two different types of material to fill the voids between the stones of the erosion barrier: sandy soil and controlled low strength material. Tap roots of the loblolly pine grow deep enough that sandy or backfill-type soil in the shallower parts of the erosion barrier will not deter their growth.

Path Forward

Provide information describing the DOE plans for reducing the uncertainty associated with root penetration of the ULDL, HDPE, and GCL in the closure cap and the resulting reduction of performance due to that degradation.

CBs&DLs-2
The NRC staff needs additional information regarding the DOE plans for reducing the risk-significant uncertainty associated with fine-grain deposition of particles in the ULDL and the resulting reduction of performance due to this degradation.

Basis
The DOE documents SRR-CWDA-2021-00040 and SRR-CWDA-2021-00066 demonstrated the risk-significance of the ULDL to performance. The 2009 SDF PA closure cap model represented silting-in of the drainage layers (i.e., the transport of fine particles from the overlying backfill and deposition of those particles in lateral sand drainage layers) as a possible degradation mechanism. Silting-in of the drainage layers influenced the projected closure cap performance because the projected perched water depth in the drainage layer increased when silting reduced the saturated hydraulic conductivity of the drainage layer and projected flow through defects was proportional to the perched water depth. In contrast, the DOE 2020 SDF PA closure cap model excluded degradation of the ULDL and LLDL (i.e., decreasing hydraulic conductivity) due to the process of fine-particle deposition within the coarser-grained material of the drainage layers for the following three reasons: (1) the authors of the DOE document SRRA107772-000009 did not observe infilling of fines when exhuming modern final covers or analog sites; (2) the closure cap design included a nonwoven polymeric geotextile filter above the drainage layer; and (3) the DOE expects that a natural filter will develop above the geotextile.

Although the NRC staff recommends using evidence from analog sites to support assigned parameter ranges and conceptual models, it is not clear to the NRC staff that the analog site information in the DOE document SRRA107772-000009 was sufficient to provide a strong technical basis. Silting-in strongly depends on the inflow rate. Inflow rates of 650 millimeters per year (mm/yr) [26 inches per year (in/yr)] to the ULDL sand layer are very plausible while inflow rates to the related layers of the analog sites appear to be orders of magnitude smaller due to the construction approach. Although the climate for the area in which the Tu-Dun tomb is located is similar to that that of the SRS, the gradient for most of the tomb is such that the NRC staff expects that surface runoff is a major component of the tomb's water budget. While the DOE expects that surface runoff for the closure cap will be 5 percent of the expected precipitation at the SDF (see Figure 3.2-35 in the DOE 2020 SDF PA), the Kyushu burial mound and Tu-Dun tombs described in the DOE document SRRA107772-000009 were expressly designed to shed flow.

Also, the NRC staff notes that, although the Tu-Dun tombs were built with alternating layers of cohesive soil and red sandy soil, the Kyushu burial mound site in Japan used alternating layers of clay and loam, which is different than the current SDF cover design (i.e., drainage layer will be made of sand). The authors of the DOE document SRRA107772-000009 also referenced fine-over-coarse layering at natural analog sites in the State of Washington. However, those analog sites are not ideal analogs because they are natural and the layers observed were not artificially constructed. There is a potential that natural soil structures at a natural site may behave differently than soil in an engineered surface cover due to the disturbed characteristics of the soil within a cover.

Furthermore, it is not clear to the NRC staff that the visual presence of a persistent sharp interface between different layers precludes the migration of fines because direct measurement of fines deposition is lacking. Cumulative fine migration into a coarser medium is dependent on the cumulative number of pore volumes passing from fine to coarse and the SDF location is designed to have large flow into the ULDL over long periods of time. The authors of the DOE document SRRA107772-000009 did not address differences in cumulative pore volumes. For example, the provided example of a modern cover in Nebraska was specifically designed to minimize flow into the sand layer and was only in place for eight years. The Nebraska inflow likely represents a fraction of a year of SDF inflow. The authors of the NRC document NUREG/CR-7028 exhumed geotextiles and geonets for modern-day covers after less than six years of service and described there being a modest amount of soil present in many of the geotextiles and a coating of fines in some of the geonets. The presence of fines in a geonet suggests that silting-in is a viable process. However, the DOE document SRR-CWDA-2021-00031 indicated that the DOE expects the presence or accumulation of fines on the surface of geotextiles or directly above a coarse earthen layer and the DOE did not believe it is indicative of 'silting in' that might occur with higher energy (e.g., in a fluvial environment). The DOE document SRR-CWDA-2021-00031 also suggested that the finer particles that accumulate at a geotextile form bridges across the larger pores in the coarser material below and create a thin 'filter' layer that keeps the underlying drainage material free of fines. Yet, as stated above, silting-in strongly depends on the flow rate and the flow rates into the planned SDF cover will be considerably higher than into the covers at the examined sites studied in the NRC document NUREG/CR-7028, more similar to a fluvial environment with higher energy, and may be sufficient to induce migration of fines into a drainage layer.

A degradation mechanism moving significant number of fines vertically into the ULDL and thereby lowering its hydraulic conductivity appears likely given the relatively high energy inflow rates. If fines accumulating on and above the overlying geotextile filter were to increase, then the rate of fine migration into the ULDL may decrease over time. However, that may also increase the likelihood that any perched water in the backfill above the fine 'filter' layer will increase.

Path Forward

Provide information describing the DOE plans for reducing the uncertainty associated with fine-grain deposition of the ULDL and the resulting reduction of performance due to this degradation.

CBs&DLs-3

The NRC staff needs additional information regarding documenting the high level of Quality Assurance/Quality Control (QA/QC) applied during the emplacement and installation of the composite barrier layers in mud mats.

Basis

The CNWRA report included studies that suggested that initial and construction-related defects historically have tended to be more frequent and larger than assumed in the DOE 2020 SDF PA. The assumption that careful construction practices will preclude construction-related defects may be an achievable goal; however, the available data suggests that infiltration rates would be greater than described in the DOE 2020 SDF PA Closure Cap Model.

In the DOE 2020 SDF PA, the DOE assumed that there were five initial HDPE defects per hectare. That assumed value might be defensible given the high level of QA/QC expected. As part of closure cap construction, the DOE 2020 SDF PA indicated that the DOE will perform HDPE installation, detection of defects, and repairs of defects according to standards established by the ASTM. The DOE 2020 SDF PA also indicated that the DOE will place the GCL using QC standards to minimize wrinkles and irregularities. The DOE 2020 SDF PA further stated that, depending on the seam welding method used during construction, the DOE will test each seam for defects using vacuum testing, spark testing, air channel pressure testing, or shear and peel testing, and then the DOE will repair all identified defects.

Path Forward

Provide documentation demonstrating the high level of QC applied during the installation of the composite barrier layers in the mud mats for SDS 2A, SDS 2B, SDS 3A, SDS 3B, SDS 5A, SDS 5B, SDS 6, SDS 7, SDS 8, and SDS 9. Provide documentation on how all wrinkles were removed during the installation and how the composite barrier layers were tested for defects. For example, the DOE document C-SPP-Z-00019 (ADAMS Accession No. ML20206L006) provided specifications for ongoing installation of composite barrier layers emplaced in mud mats and indicated that the DOE identified and repaired defects according to ASTM standards.

CBs&DLs-4

The NRC staff needs additional information regarding the DOE plans for avoiding wrinkle formation on conical surfaces and information demonstrating that leakage rates through repair patches will not become risk-significant.

Basis

Good contact between the HDPE geomembrane and GCL is important for limiting leakage from a defect because poor contact can increase lateral flow under the defect. When geomembranes contain wrinkles or when they are not resting on a solid surface, gaps can form between the geomembrane and GCL so that good contact is lost. The current DOE conceptual design of the closure cap and engineered barriers above the disposal structures may create composite barrier wrinkles or seam integrity issues in areas where the underlying surface is not planar (i.e., has curvature). Such wrinkles would be inherent to the geometric configuration and cannot be resolved with QC alone (e.g., the previous breach in SDS 3A). A change in slope, such as the toe of a basin side slope, is typically associated with poor contact between the HDPE and GCL; although, the current DOE design concept does not contain large breaks in slope.

In addition, curvature in two directions may be of particular concern in the closure cap, because rectangular panels cannot cover such surfaces without wrinkling, cutting, or stretching (such as, wrapping a ball with paper). The conical roofs of the cylindrical disposal structures is an example where wrinkles may form in the LLDL composite barrier layer without mitigating efforts. The configuration of the ULDL is not indicated in the DOE 2020 SDF PA; but surface contours shown in the SDF closure cap design configuration (see Figure 3.2-29 in the DOE 2020 SDF PA) indicated that the closure cap surface was a mix of planar and conical zones, suggesting that the ULDL would have a similar mixture. With sufficiently tight curvature, areas of the ULDL with conical configurations may need special consideration to avoid additional tensile stresses on the geomembrane or difficult seam conditions.

Repair patches also may cause good contact to be lost between the HDPE geomembrane and the underlying GCL or substrate. For example, the 2019 Gilson-Beck article in **Geotextiles and Geomembranes** quantified leakage rates of ~230 liters/hectare/day (>8 mm/yr) (>0.3 in/yr) through a 1.5-mm (0.06-in) HDPE geomembrane over a GCL due to six pinholes in extrusion welds and a 4-mm (0.16-in) puncture with the pinholes appearing to be aligned with extrusion-welded repair patches along a seam.

Path Forward
Provide information demonstrating that wrinkle formation on conical surfaces (e.g., roofs, radial curvature of the ULDL) can be avoided and that leakage rates through repair patches will not become risk-significant.

CBs&DLs-5
The NRC staff needs additional information regarding the DOE plans for reducing HDPE degradation rate and service life uncertainty.

Basis
The DOE documents SRR-CWDA-2021-00040 and SRR-CWDA-2021-00066 demonstrated the risk-significance of HDPE to performance. The DOE 2020 SDF PA modeled two HDPE geomembrane thickness: (1) 1.5 mm (0.059 in) for the ULDL and most of the 375-ft disposal structure mud mats; and (2) 2.5 mm (0.098 in) for the LLDL, the 150-ft disposal structure mud mats, and the SDS 6 mud mat. The representation of HDPE degradation in the DOE 2020 SDF PA closure cap model was based on a model for HDPE antioxidant depletion and service life when exposed to low-level radioactive waste leachate, as described in a 2017 article authored by Tian et al. That model considered various experiments that used one- and two-sided immersion of 2.0 mm (0.079-in) HDPE strips with different leachate compositions.

In the 2017 article, the authors (Tien et al.) used a three-stage model for service life predictions with predictions based on a 2 mm (0.079-in) HDPE geomembrane at 15°C (59°F). Stage 1 (antioxidant depletion) calculations were based on one-sided exposure experiments with synthetic low-level radioactive waste leachate with an estimated antioxidant depletion time of 750 years. Stage 2 (induction) and Stage 3 (polymer degradation) were based on one-sided exposure experiments with municipal solid waste leachate using rate parameters reported by 2009 authors (Rowe et al.). In the 2017 article, the authors (Tian et al.) calculated a total service life of at least 1,975 years based on a criterion of failure at 50 percent loss of stress crack resistance. Because degradation rates for the 1.5-mm (0.059-in) HDPE geomembrane were based on one-sided exposures of a 2.0-mm (0.079-in) HDPE geomembrane and the time for a reaction front to penetrate a fixed distance is proportional to the square of the distance (see Section 4.4.2.1 in the DOE 2020 SDF PA), the thinner geomembrane will likely attain an equivalent diffusion-based depletion status approximately 1.8 times faster than the thicker geomembrane.

The HDPE geomembrane in the composite barrier layer underlying the ULDL may have significantly different conditions on the two sides, which implies that degradation may occur at different rates. The ULDL will have an episodic or perennial water table perched on the composite barrier layer to drain inflow. The scenario of a HDPE geomembrane that is saturated on one side and has a GCL on the lower side was not tested. Soil gas oxygen available below the GCL may diffuse through the GCL allowing at least partial degradation on the bottom of the geomembrane. Degradation of the underside of the geomembrane by diffusion through the underlying GCL may be slower; but still increase degradation rates relative to one-sided diffusion.

The DOE based the degradation model for the composite barrier layers and HDPE geomembrane layers below the closure cap on the performance of the composite barrier layer in the cover. Compared to the closure cap composite barrier layer, the chemical environment will be more diverse within the disposal structure concrete components (e.g., roof, walls, mud mats) than the clayey soil used for the foundation layer in the cover. Over time, dissolved saltstone and concrete constituents (including radionuclides) will diffuse from the saltstone toward the GCL. The DOE predicted the disposal structure roof concrete will have a pH of at least 12.5 for at least 565 years (i.e., SDS 4) to 793 years (i.e., SDS 9) for the compliance case assumptions (see Section 4.4.3.4.3 in the DOE 2020 SDF PA). A highly alkaline environment may speed antioxidant depletion rates without additives to the HDPE geomembrane and thus, the adjacent HDPE geomembranes may degrade more rapidly and the adjacent GCLs may not perform as expected.

The degradation model in the DOE 2020 SDF PA used a generic temperature to estimate degradation rates without correcting for the site temperature, even though degradation rates are sensitive to temperature. In the 2017 article, the authors' (Tian et al.) service life calculations assumed a temperature of 15°C (59°F). The analysis in the DOE document WSRC-STI-2008-00244 (ADAMS Accession No. ML101600430) used 22°C (72°F) for HDPE degradation calculations. Using the 2017 (Tian et al.) values for the three degradation stages with the 22°C (72°F) site temperature, overall degradation time would decrease.

Path Forward

Provide information describing the DOE plans for reducing HDPE degradation rate uncertainty and HDPE service life uncertainty. Specifically, provide information on the DOE plan for reducing the uncertainties associated with assuming degradation rates for the 1.5-mm (0.059-in) HDPE geomembrane based on one-sided exposures of a 2.0-mm (0.079-in) geomembrane, HDPE geomembranes underlying the ULDL and LLDL may have different conditions on the two sides, and service life calculations assuming a temperature of either 15°C (59°F) or 22°C (72°F).

CBs&DLs-6

The NRC staff needs additional information regarding the degradation rates at heat-affected zones on seams and at wrinkles in the HDPE geomembranes to determine whether degradation in those areas will lead to an increased risk-significant degradation of the composite barrier layers.

Basis

The HDPE degradation model used in the DOE 2020 SDF PA and supplemented with the DOE Responses to the NRC request for supplemental information (RSI) comments (ADAMS Accession Nos. ML21159A059, ML21089A119, ML21160A059, ML21217A076) did not specifically address degradation related to specific features that are known to have low resistance to stress or large local stresses. Those features would be prone to developing defects even when stress levels are too small to develop defects over most of the geomembrane. It is not clear to the NRC staff that the degradation rates for intact HDPE geomembranes apply to the most vulnerable locations.

In a 2019 article, the authors (Rowe et al.) considered welded seams to be the most critical locations for failure based on experiments showing that: (1) material adjacent to the seam degraded twice as fast as the surrounding sheet; and (2) the heat-affected zone adjacent to the seam magnified strains by a factor of 2.3 to 4.0 (from a 2017 article authored by Kavazanjian et al.). Heat-affected zones, which occur near welded seams, are known to have enhanced leaching of antioxidants and low resistance to stress cracking. The DOE 2020 SDF PA and DOE RSI responses did not specifically address preferential failure along heat-affected seams, although the initial defect frequency appears to be based on recommendations by the 1989 authors (Giroud and Bonaparte) that were based on initial seam defects.

Wrinkles are another feature that could cause degradation. They are known to have locally intense stress concentrations and to be difficult to eliminate. They also are known to have large consequences with respect to infiltration. The DOE document SRR-CWDA-2021-00033 (ADAMS Accession No. ML21160A062) included that wrinkles can be limited with careful installation of the HDPE and the overlying material and possibly perform indefinitely as an impermeable layer. Although eliminating wrinkles may be possible, the literature suggests that even extreme care during construction may not eliminate all wrinkles.

Path Forward
Provide information demonstrating that HDPE degradation rates, based on the degradation rates for intact HDPE geomembranes as opposed to wrinkled or heat-affected zones, will not underestimate the degradation rate of the composite barrier layers in a risk-significant manner. Alternatively, provide information describing the DOE plans for reducing the uncertainty associated with wrinkles and heat-affected zones near seams and the resulting reduction of performance due to that degradation.

CBs&DLs-7
The NRC staff needs additional information regarding the degradation rates at the edges of defects in the HDPE geomembranes to determine whether degradation in those areas will lead to an increased risk-significant degradation of the composite barrier layers.

Basis
The basis that the DOE provided for the HDPE degradation rates in SRR-CWDA-2021-00033 included tests performed with fully immersed samples. Tests of fully immersed samples do not measure degradation of edges of a defect, which are likely to degrade faster than areas away from edges because of the diffusion perpendicular to the exposed edge. Water will drain through a defect and spread underneath, allowing the moisture state to locally equalize on all sides of the HDPE geomembrane near the defect as if the edge were fully immersed. The edge of a fully immersed sample is likely to degrade faster than degradation measured away from the edge and the assumed one-sided degradation rate; however, samples were usually measured away from the edge. For example, the DOE 2020 SDF PA degradation calculations for enlarging a defect were based on the 2017 calculations (authors Tian et al.) for one-sided diffusion during Stage I (antioxidant depletion), which multiplies the calculated time determined using full-immersion tests by a factor of 3.4 instead of reducing the calculated time to account for edge effects.

Path Forward
Provide information demonstrating that HDPE degradation rates, based on the one-sided degradation rates away from fully immersed edges, will not underestimate the degradation rate of the composite barrier layers in a risk-significant manner. Alternatively, provide information describing the DOE plans for reducing the uncertainty associated with degradation at the edges of defects and the resulting reduction of performance due to this degradation.

CBs&DLs-8
The NRC staff needs additional information regarding the ULDL to determine whether the ULDL could plausibly become confined and, if it could, whether a confined ULDL will lead to a risk-significant increase in the infiltration rate to the LLDL.

Basis
The DOE 2020 SDF PA closure cap model, as supplemented with the DOE responses to the NRC request for RSI comments, calculated vertical inflow to the ULDL sand layer using a

1-dimensional numerical model and calculated total infiltration by multiplying the single-defect infiltration flow by the number of assumed defects. The model then averaged total infiltration across the area of the cover and passed the calculated average infiltration rate to the Vadose Zone Flow Model as the equivalent uniform infiltration. In essence, the DOE three-step procedure assumed that: (1) the defects are so widely separated that flow calculations for a defect are not influenced by flow removed by any other defect; and (2) the sand layer remains unconfined (i.e., the perched water table within the sand layer does not rise to the top of the sand layer). The DOE 2020 SDF PA approach of applying a 1-dimensional vertical numerical model to estimate inflow to the drainage layer is reasonable when unconfined conditions exist throughout the sand layer of the ULDL.

Although using the calculated inflow from the most adverse location across the entire cap was intended to be conservative by the DOE, the approximation may substantially underestimate risks for some of the cases presented in the DOE 2020 SDF PA, especially the sensitivity cases described in Section 5.8.3.1. The cases of concern arise when the ULDL becomes confined. In those cases, the thickness of the drainage layer becomes saturated and the top of the perched water reaches up into the middle backfill causing the downward gradient above any defect below to increase. The middle backfill has a much smaller hydraulic conductivity than the drainage layer, acting as a confining unit, and the constriction pressurizes the ULDL drainage layer. Pressurization may have two consequences: (1) a near quadratic increase in flow through the defect; and (2) a perched water table existing in the overlying backfill that may limit the capacity for inflow to the backfill, thereby increasing runoff and erosion of the cover.

The results of modeling in the CNWRA report showed that confined conditions can occur even under shorter slopes when the ULDL hydraulic conductivity decreases resulting in peak infiltration values much larger than used in the DOE 2020 SDF PA. Although the DOE modeled greater infiltration rates in the DOE document SRR-CWDA-2021-00066, it is not clear to the NRC staff that the model, as supplemented, accounted for all the effects of a perched water table. If the calculated perched water table is above the ground surface, then the assumed inflow to the ULDL is clearly too large, so that water would be forced to pond on the surface or run off instead of infiltrating. Increased runoff implies that there is a potential for increased erosion. The CNWRA numerical model results suggested that the condition may occur during wet years if the ULDL saturated hydraulic conductivity is just a factor of two smaller than the Compliance Case values. Seasonable variability also may substantially influence annual-average infiltration especially for wet years with seasonal inflow substantially larger than 650 mm/yr (26 in/yr) in wet years.

The CNWRA report suggested that the DOE 2020 SDF PA calculations related to infiltration, as supplemented by the RSI responses, may not be applied consistently with their theoretical underpinnings for the following reasons:

- The flow system may have very different behavior when the perched water table is confined instead of unconfined; once the threshold creating a confined system is crossed, there is a dramatically increased potential for elevated infiltration, elevated surface runoff, and elevated surface erosion.

- The ULDL hydraulic conductivity is an important parameter for calculating infiltration and a small uncertainty in this parameter appears to have potentially large consequences for infiltration, surface runoff, and erosion of the cover.

- The inflow to the ULDL has a large influence on whether the ULDL perched water table becomes confined when the water table nearly fills the ULDL. It may be more appropriate to consider seasonal and interannual variability in inflow when calculating total infiltration and designing the ULDL.

Path Forward
Provide information demonstrating that a confined perched water table within the ULDL is implausible. Alternatively, provide information demonstrating that confining or partially confining conditions within the ULDL will not lead to a risk-significant increase in the infiltration rate to the LLDL.

CBs&DLs-9
The NRC staff needs additional information regarding the results of an analysis that includes a degraded GCL immediately below HDPE geomembrane defects. The NRC needs information demonstrating that the degradation of the GCL immediately below defects in the HDPE geomembrane will not occur or lead to a risk-significant increase in the infiltration rate to the LLDL.

Basis
The CNWRA report concluded that the technical bases for the model approach used for the GCL have a low strength for the following reasons:

- The technical basis did not appear to consider that only the portion of a GCL that experiences flow from a defect influences the rate of flow through the defect.

- The DOE 2020 SDF PA supporting documents with referenced GCL properties did not specifically address interactions of GCLs with localized flow from defects.

- The analyses in a 2018 report (authored by Benson and Benavides) based the long-term GCL properties on seven GCL samples from the nearby Barnwell Disposal Facility. All of those samples were obtained after 14 years under an in-situ HDPE geomembrane. Those samples experienced stagnant flow conditions for the entire installation period with limited opportunity for cation transfer into the GCL and showed little or no cation exchange.

- Other documents (e.g., NRC NUREG/CR-7028, 2011 document authored by Scalia and Benson) reported measurements of exhumed GCLs from several sites that did not experience stagnant flow conditions for the entire installation period with all samples showing partial to complete cation replacement after five to seven years in service. A number of samples were obtained from GCL-only installations, which are directly analogous to those portions of a GCL under a flowing defect. The NRC NUREG/CR-7028 concluded that the GCL ceased functioning as a hydraulic barrier within several years after installation as a sole barrier.

The DOE based values used in the DOE 2020 SDF PA for the GCL in the cap composite barrier layer on the approach used by the authors Benson and Benavides in 2018. The DOE 2020 SDF PA described that GCL as maintaining a saturated initial hydraulic conductivity like that of the initial value for the GCL, regardless of whether divalent cations exchange with monovalent cations in the GCL, as long as the substrate was placed on a moist subgrade and covered with an HDPE geomembrane and soil. In addition, the authors (Benson and Benavides) expressed the view that it was more relevant to assess the cover performance based on the seven Barnwell GCL samples than it was to use the other data discussed above. However, given the model assumptions, the selected values in the Closure Cap Model for the expected value and upper bound values for GCL hydraulic conductivity may not be appropriate to use because the

GCL areas below the HDPE holes determine flow rates even if the selected properties described most of the composite barrier layer in the cover.

The DOE closure cap model assumed that the only long-term defects were the initial defects. Initial defects will experience flowing conditions starting soon after installation; therefore, the section of the GCL that controls performance will also experience flowing conditions that allow continual modification of the bentonite chemistry. Because none of the Barnwell samples were described as experiencing flow through a defect, those samples did not provide information regarding the consequences of delayed onset of flow through the GCL after rehydration was completed. Accordingly, the most relevant GCL property values to assigned in a performance assessment may be associated with GCL-only samples because those samples experienced a continual flow of pore water through the GCL. In essence, the GCL under a defect is the sole barrier to flow through the defect. The NRC NUREG/CR-7028 concluded that GCLs used as the sole barrier layer typically become very permeable within several years after installation and cease functioning as a hydraulic barrier. Assuming that the GCL is the sole flow barrier below an HDPE defect, the data would imply that within a decade, expected infiltration rates through initial defects in the ULDL composite barrier could significantly increase.

Path Forward

Provide results of an analysis with a degraded GCL immediately below HDPE geomembrane defects using revised compliance case infiltration rates as shown in Figure 6.3-1 in the DOE document SRR-CWDA-2021-00040 and saltstone saturated hydraulic conductivity values as suggested in the DOE document SRR-CWDA-2021-00056. A defect in the HDPE geomembrane of the three composite barrier layers (i.e., cap, roof, mudmat) should be accompanied by a GCL immediately below that defect that has also experienced complete failure (e.g., for the cap, a vertical hydraulic conductivity equal to that of backfill (4.1×10^{-5} centimeters per second (cm/sec)). Alternatively, provide information demonstrating that the degradation of the GCL below defects in the HDPE geomembrane will not occur or lead to a risk-significant increase in the infiltration rate to the LLDL.

CBs&DLs-10

The NRC staff needs additional information regarding the results of an analysis that includes a relatively small areal extent of contaminant release from the disposal structure to the water table.

Basis

It is plausible that the two differently located composite barrier layers (i.e., above the roof, within the mud mat) will degrade at different rates because the environment of their locations will differ. In addition, the number of seams per area will possibly differ because the composite barrier layers above the roof will be covering conical roofs of the cylindrical disposal structures (see CBs&DLs-4 above) and likely require more seams per area. If the roof composite barrier degraded at a quicker rate than the composite barrier in the mud mat, then it is possible for a given time that water exiting the disposal structure will flow over the upper lip of the mud mat composite barrier layer around the perimeter of the disposal structure if the gradient of the mud mat remains level or over the lip at one side of the disposal structure if the mud mat does not stay level. Unlike the flow and transport through a fast pathway, such as a crack or a fracture, radionuclide release in that alternative conceptual model will have occurred due to matrix flow through the saltstone. Given that the alternative conceptual model differs from the Compliance Case in that the level of contaminant concentration in the vadose zone will be higher and result in a smaller water table area where the radionuclides are transported into the aquifer, a comparative analysis would provide useful information.

Path Forward
Provide results of an analysis that includes a relatively small areal extent of contaminant release from the disposal structure to the water table using the revised pessimistic case and realistic case infiltration rates, as shown in Figure 6.3-1 of the DOE document SRR-CWDA-2021-00040. (Note that the area of the release would be fraction of the size of the bottom area from the disposal structure.) Alternatively, provide information demonstrating that a relatively small areal extent of contaminant release from the disposal structure to the water table is not plausible.

RAI Questions for the Technical Topic of Radionuclide Release (RR):

RR-1
The NRC staff needs additional information regarding the projected sorption of Iodine-129 (I-129) in certain areas of saltstone grout and disposal structure concrete.

Basis
Figure 5.8-83 in the DOE 2020 SDF PA included four diagrams of SDS 7 showing the projected reducing capacity, buffering capacity, aqueous I-129 concentration, and total I-129 concentration at 10,000 years after SDF closure. The diagram of total I-129 concentration (i.e., the bottom diagram in Figure 5.8-83) showed two narrow bands of red (i.e., corresponding to the highest I-129 concentration) near the bottom of SDS 7 and one vertical band of red in the middle. The diagram of aqueous concentrations of I-129 in Figure 5.8-83 (i.e., third diagram from the top) did not show elevated aqueous concentrations in those areas, which indicated that the aqueous concentration did not account for the high total concentration. Therefore, the red bands in the diagram of the total I-129 concentration appeared to show areas of high I-129 sorption.

Those areas also coincided with areas of lower chemical reducing capacity in the same figure (i.e., the top diagram in Figure 5.8-83 in the DOE 2020 SDF PA). That pattern was consistent with the DOE description of the Vadose Zone Transport Model because the modeled sorption coefficient for I-129 was greater in oxidized Region III (RIII) cementitious material than it was in chemically reduced Region II (RII) or RIII cementitious material. However, it is not clear to the NRC staff that reduced I-129 would oxidize while flowing through oxidized cementitious material. That is, it is not clear to the NRC staff whether the oxidation of reduced I-129 would occur before the I-129 flowed through the oxidized regions. Furthermore, because the bands of high I-129 sorption corresponded to the highest I-129 concentration on the color scale in Figure 5.8-83, it is not clear to the NRC staff whether those bands represented concentrations significantly greater than the original I-129 concentration in saltstone. Therefore, it is not clear to the NRC staff whether the effect was a modeling artifact.

Increased sorption of I-129 in oxidized RIII cementitious material is risk-significant because the sorption of I-129 in an oxidized rind around saltstone is a key feature of the shrinking-core model of I-129 release, which significantly affects the projected dose from I-129. For example, the DOE response to RAI question RR-5 in the NRC second set of RAI questions

(SRR-CWDA-2021-00072, ADAMS Accession No. ML21321A087) demonstrated that using a simpler model of I-129 release increased the I-129 contribution to the projected peak dose to a member of the public within 10,000 years by 200 percent in the realistic case, 120 percent in the compliance case, and 89 percent in the pessimistic case (see Table RR-2.5 in SRR-CWDA-2021-00072). The realism of those projections depends on the sorption of I-129 as it is transported through oxidized saltstone. Therefore, it is not clear to the NRC staff whether the simpler model provided an accurate projection of I-129 release from saltstone and the disposal structures.

Path Forward
Provide numerical values for the I-129 concentrations in the narrow red bands in the diagram of the total I-129 concentration in Figure 5.8-83 in the DOE 2020 SDF PA and assess the realism of those concentrations. Provide a technical basis for assuming that chemically reduced I-129 flowing through oxidized saltstone or disposal structure concrete would oxidize before it exited the oxidized area.

RR-2
The NRC staff needs additional information regarding the technical basis for the K_d value that the DOE used to represent iodine sorption in saltstone under Oxidizing Region III conditions in saltstone made with the new cement-free formula.

Basis
In the NRC second set of RAI questions (ADAMS Accession No. ML21133A293) for the DOE 2020 SDF PA, the NRC staff requested additional information to support the DOE determination that literature values based on I-129 sorption in oxidized concrete adequately represented projected I-129 sorption in oxidized saltstone. In the basis for the NRC RAI question RR-2 in that document, the NRC staff summarized the issue as follows:

> "Unlike the sorption coefficients for iodine in saltstone under chemically reducing conditions, which were based on experiments with simulated saltstone cores, the K_d value the DOE used to represent iodine sorption under oxidizing conditions was based on the results of several different experiments with ordinary concrete that the DOE referenced in the DOE document SRNL-STI-2009-00473, Rev. 1 (ADAMS Accession No. ML17047A417). In that document, the DOE indicated that iodine sorption to concrete tends to increase as the ratio of calcium (Ca) to silicon (Si) increases. That indicates that the sorption of iodine on saltstone could be less than its sorption on concrete because saltstone contains less ordinary Portland cement than concrete, giving it a lower initial Ca/Si ratio. Other variables, such as the absence of aggregates from saltstone, also could affect iodine sorption."

The DOE response to the RAI question RR-2 in the NRC second set of RAI questions (SRR-CWDA-2021-00072) indicated that the K_d for I-129 in oxidized cementitious materials should be greater than the K_d for I-129 in chemically reduced cementitious material because of an expected chemical change between iodine to iodate. Based on that change, the DOE expected the K_d for I-129 in oxidizing cementitious materials to be greater than the K_d value of 0.71 milliliter per gram (mL/g) for I-129 in reduced cementitious material in the compliance case. To justify the specific value of 4.0 mL/g, the DOE provided literature values based on ordinary cementitious materials, including concrete. However, the DOE response also did not address the applicability of the cited literature values to either standard or cement-free saltstone. Although the DOE document SRR-CWDA-2020-0008 provided support for modeled I-129 sorption in cement-free saltstone under chemically reducing conditions, it did not address I-129 release from grout under chemically oxidized conditions.

The DOE response provided a sensitivity analysis of a model of I-129 release that modeled a system without an oxidized rind forming during the performance period (i.e., a non-shrinking-core model). As seen above in RR-1, the DOE response to RAI question RR-5 in the NRC second set of RAI questions (SRR-CWDA-2021-00072) demonstrated that using a simpler model of I-129 release significantly increased I-129 contributions to the projected peak dose to a member of the public within 10,000 years in the realistic, compliance, and pessimistic cases. The realism of those projections depends on the K_d value for I-129 in oxidized RIII grout made with both standard and cement-free saltstone. Therefore, it is not clear to the NRC staff whether the simpler model provided a more accurate projection of I-129 release than the shrinking-core model.

Path Forward
Provide information to support the DOE K_d value for I-129 in oxidized RIII cementitious material. If the technical basis includes a comparison to values measured on oxidized concrete, then address the applicability of the cited literature values to both standard and cement-free saltstone grout. The DOE Response should address the relative Ca to Si ratios and the potential influence of aggregates in concrete on the cited literature values.

RR-3
The NRC staff needs additional information regarding the technical basis for the K_d value that the DOE used to represent Technetium (Tc) sorption in saltstone under Oxidizing Region III conditions in cement-free saltstone.

Basis
The DOE document SRR-CWDA-2020-0008 showed similar leach rates for Technetium-99 (Tc-99) from samples of cement-free saltstone and standard saltstone under chemically reducing conditions, when the DOE expected Tc leaching to be limited by solubility. However, that DOE document did not address leaching from oxidized saltstone, which the DOE expected to be limited by sorption rather than solubility. It is not clear to the NRC staff that measurements of Tc sorption on oxidized disposal structure concrete or oxidized standard saltstone apply to oxidized cement- free saltstone.

Figure 5.8-33 in the DOE 2020 SDF PA showed that the shrinking-core model in the Compliance Case caused earlier releases than a non-shrinking-core model in which saltstone remained chemically reduced during the performance period. The projected Tc release rate from oxidized nodes in the shrinking-core model depended on the assumed K_d value for Tc in oxidized RIII saltstone. Therefore, the NRC staff expects projected Tc releases at early times (e.g., before 2,000 years) to depend on the assumed K_d for Tc in oxidized RIII cement-free saltstone.

Path Forward
Provide information to support the assumed K_d value for Tc-99 in oxidized RIII cement-free saltstone grout.

RAI Questions for the Technical Topic of Sensitivity and Uncertainty Analyses (SUA)

SUA-1

The NRC staff needs additional information on the relationship between peak infiltration and peak dose in the DOE response to the NRC request for supplemental information comment RSI-1.

Basis

Figure 3 in the DOE document SRR-CWDA-2021-00098 (ADAMS Accession No. ML21326A013) showed the relationship between the peak infiltration rate and peak dose within 10,000 years for a subset of realizations from the DOE model for the DOE responses to RSI-1. In that document, the DOE stated, "Based on the distribution of data points in this figure, it appears that if infiltration rates through the SDF closure cap can be limited to less than [2.5 cm/yr (1.0 in/yr)], the resulting peak doses would be unlikely to exceed 25 mrem/yr." However, because of the criteria the NRC requested to select the data subset, Figure 3 did not include realizations with peak infiltration rates less than 2.5 cm/yr (1.0 in/yr).

Path Forward

Provide a figure showing the relationship between the peak dose within 10,000 years of site closure and the peak infiltration rate (e.g., similar to Figure 3 in SRR-CWDA-2021-00098) that includes all the realizations the DOE developed in response to the NRC request for supplemental information comment RSI-1. If needed to provide risk insights for realizations that do not appear to be consistent with the general trend in the figure, then the DOE could partition the data with color coding to highlight the effects of other significant parameter choices.

SUA-2

The NRC staff needs additional information regarding the sensitivity of model projections to several key parameters in cases modeled with the revised recommended infiltration rates shown in Figure 6.3-1 in the DOE document SRR-CWDA-2021-00040 and degraded performance of the LLDL, composite barriers above the disposal structure roofs, and saltstone grout.

Basis

Section 5.8 in the DOE 2020 SDF PA provided sensitivity analyses based on the compliance case. However, the compliance case used infiltration rates that were much lower than the rates the DOE recommended to use in performance assessments (see SRR-CWDA-2021-00040). In addition, the compliance case used performance projections for the LLDL and composite barrier above the disposal structure roofs that did not include all relevant degradation mechanisms (see NRC preliminary review letter, ADAMS Accession No. ML20254A003). The NRC staff expects that both increased infiltration and increased degradation of the LLDL and composite barrier could increase flow through saltstone significantly, as well as the additional saltstone degradation assumed in the NRC request for supplemental information comment RSI-1 analysis. Because of the complexity of the modeled system (e.g., feedback between flow and degradation, shrinking-core model for Tc-99 and I-129 release), it is not clear to the NRC staff whether several of the risk insights from Section 5.8 in the DOE 2020 SDF PA apply in cases with increased flow.

Path Forward

Provide revisions of the sensitivity cases shown in Table 1 (see below) using: (1) the infiltration rates the DOE recommended in Figure 6.3-1 in the DOE document SRR-CWDA-2021-00040 and (2) parameter values for the engineered barriers in the vadose zone (e.g., LLDL, roof composite layer, disposal structure concrete, saltstone, floor composite barrier) consistent with the assumed barrier performance in the DOE response to the NRC request for supplemental information comment RSI-1. For engineered barriers that were not specifically addressed in comment RSI-1, the DOE should use values that are consistent with values assigned in comment RSI-1 (e.g., assumptions about the floor composite barrier should be consistent with assumptions about composite barriers in other parts of the system, taking different placement conditions into account). The assumed performance of those engineered barriers should allow for an understanding of the risk-significance of the barrier being analyzed. As evaluated in the DOE 2020 SDF PA, provide contaminant release information for Cl-36, Tc-99, and I-129.

Although some of the cases below showed small effects on the projected dose in the original analysis, the NRC staff selected these cases because the sensitivity of the projected dose to the parameter change could be significant at larger flow rates.

Table 1. Sensitivity Cases from the DOE 2020 SDF PA that the NRC Staff Expects Could Provide Different Risk Insights in Cases with Greater Flow Reaching the Wasteform

Topic	DOE 2020 SDF PA Section	NRC Staff Reason for Selecting the Topic
Controlled compacted backfill K_{sat}	5.8.3.2	Increased infiltration rates through the backfill would increase the relative rates of contaminant releases and transport to the water table and could cause this parameter to become more risk-significant
Disposal Structure Concrete Initial K_{sat}	5.8.3.3	Increased infiltration and degraded performance of the LLDL and composite barrier above the disposal structure roofs could cause this parameter to become more risk-significant by increasing the relative flow restriction imposed by the concrete K_{sat} (i.e., by increasing the flow the concrete K_{sat} would restrict)
Saltstone Initial K_{sat}	5.8.3.4	Increased infiltration and degraded performance of the LLDL and composite barrier above the disposal structure roofs could cause this parameter to become more risk-significant by increasing the relative flow restriction imposed by the K_{sat}
Cementitious Degradation Rate	5.8.3.5	Increased infiltration and degraded performance of the LLDL and composite barrier above the disposal structure roofs could cause this parameter to become more risk-significant by making more water available to flow through the degraded saltstone
Technetium Solubility	5.8.4.1	Because the shrinking-core model and the solubility-only models used in Section 5.8.4.1 have different dependencies on water flow, increased flow through saltstone could change the risk insights gained from the sensitivity analysis

Design Margin Case for 375-ft Diameter Disposal Structures	5.8.7.1	Increased infiltration and degraded performance of the LLDL and composite barrier above the disposal structure roofs could cause changes to the disposal structures to become more risk-significant
Saltstone Disposal Structure 4 Waste Bags Evaluation	5.8.7.3	This sensitivity analysis included increased infiltration through the closure cap. However, it is not clear if that analysis included performance of the LLDL, composite barrier above the disposal structure roofs, and disposal structure roofs. The NRC staff does not expect these materials to provide any performance if significant subsidence occurs. If the sensitivity analysis in the DOE 2020 SDF PA did include performance from these materials, then revised sensitivity analyses without these materials reducing infiltration could show an increased risk from settlement due to compression of the waste bags
Fast Flow Paths	5.8.8.2	The DOE analysis showed the risk-significance of fast flow paths was greater for cases with more advection, which the NRC staff expects to increase with increased infiltration and degraded performance of the LLDL and composite barrier above the disposal structure roofs
Early Release Cases	5.8.9.1	Increased infiltration and degraded performance of the LLDL and composite barrier above the disposal structure roofs could cause barrier performance to become more risk-significant than previously shown by increasing the flow that the barriers could divert from the wasteform

Clarifying Comments (CC) About the DOE 2020 SDF PA from the NRC Staff:

CC-1

Clarify the number and location of the thermocouples that will be installed in the 375-ft diameter disposal structures to verify temperature of the grout and air in the disposal structures.

CC-2

Several statements in Section 3.3.1.5 in the DOE 2020 SDF PA seem to imply that reductions in radionuclide concentrations from the Salt Waste processing Facility (SWPF) treatment were not considered in the development of SDF inventory. For example, Section 3.3.1.5 in the DOE 2020 SDF PA included: "To estimate the inventory of the remaining space [in SDS 3A], a ratio of the empty volume to the total SDF available volume was multiplied by the current total Tank Farm inventory." Similarly, the same section included: "It was assumed that the entire soluble and insoluble (salt) inventory present in both tank farms was divided evenly across all remaining [disposal structure] space (including the remaining volume in [SDS 3A] volumetrically." Please clarify those statements, if necessary, to indicate how the DOE accounted for the SWPF treatment.

CC-3
The DOE Response to comment CC-2 in the NRC RAI question set #2 indicated that the biosphere model for the DOE 2020 SDF PA assumed that 130 cm (52 in) of irrigation water is taken in by plants annually. However, the GoldSim model multiplies the irrigation rate by the fraction of the year the resident irrigates crops to find an effective irrigation rate. For example, the deterministic value assigned to the element “FracYearIrrigate” is 0.192 (unitless), resulting in an effective irrigation rate (i.e., “EffIrrigationRate”) of 24.96 cm/yr (9.98 in/yr) in the deterministic case. Therefore, instead of comparing the irrigation rate of 130 cm/yr (52 in/yr) to the values in Table CC-2.1 of the DOE Response to Comment CC-2, it appears to be more appropriate to compare a value of 24.96 cm/yr (9.98 in/yr) to the values in Table CC-2.1. Please clarify which is the appropriate comparison.

CC-4
Although the state of the GCL under the intact HDPE geomembrane in the current DOE conceptual model is not risk-significant, knowledge of its state provides additional insight into the moisture flow regime within the disposal facility. The authors of the DOE document SRRA107772-000009 expected the soil under the composite barrier to dry out. Please provide the assumed long-term GCL moisture content under the intact HDPE geomembranes for the cap, roof, and mudmat composite barrier layers.

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