March 31, 2010

Mr. Thomas Gutmann, Director
Waste Disposition Programs Division
U.S. Department of Energy
Savannah River Operations Office
P.O. Box A
Aiken, SC 29802

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON THE 2009 PERFORMANCE ASSESSMENT FOR THE SALTSTONE DISPOSAL FACILITY AT THE SAVANNAH RIVER SITE

Dear Mr. Gutmann:

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the "2009 Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site," (PA) dated October 2009, and the associated documentation provided. This review is being conducted in accordance with Section 3116 (b) of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005, which requires NRC to monitor disposal actions taken by the U.S. Department of Energy (DOE) for the purpose of assessing compliance with the performance objectives set out in 10 CFR Part 61, Subpart C. The PA is an update to the Performance Assessment performed in support of the "Draft Section 3116 Determination, Salt Waste Disposal, Savannah River Site," dated February 28, 2005. The updated document is changed significantly and includes a much-improved format for readability and technical clarity. The staff acknowledges the effort taken to make the document easier to navigate with the use of section summaries preceding each section and appreciates the usefulness of stating assumptions as clearly as is done in this PA. The technical scope of the updated document also is improved.

We have attached a Request for Additional Information (RAI), which is a list of comments for which the NRC staff needs responses from the DOE before the NRC can complete its review. As we continue our review of DOE documents and RAI responses, we may develop additional comments for which we will need a response from DOE. In contrast to previous reviews, the staff was provided access to computational models used by DOE during development of the PA. While receiving the models has ultimately reduced the number of NRC comments by providing detailed information about how assumptions and conceptual models were implemented, the review of the models is ongoing and may result in additional comments. The staff acknowledges timely receipt of the models upon request but for future reviews requests access to models at the time of the PA release.

In addition, we have attached the most current list of follow-up actions from NRC's monitoring activities at the Saltstone Facility. The list is being provided to show which of the follow-up actions remain open, which have been closed, and which have been closed as follow-up actions because they are reflected in the attached RAI.

To meet the current schedule and complete our review by August 31, 2010, we require responses to the RAI on or before June 1, 2010. If it would be useful to DOE, we would be willing to meet with your staff to discuss our RAI or your responses.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders," a copy of this letter will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records component of NRC's Agencywide Documents Access and Management System (ADAMS Accession Number ML100820097). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

If you have any questions, please contact Nishka Devaser, Project Manager in the Division of Waste Management and Environmental Protection, by email at Nishka.Devaser@nrc.gov, or by phone at (301) 415-5196.

Sincerely,

/RA/

Patrice M. Bubar, Deputy Director
Environmental Protection
and Performance Assessment Directorate
Division of Waste Management
and Environmental Protection
Office of Federal and State Materials
and Environmental Management Programs

Enclosures:
1. RAI
2. Follow-up Actions List

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ML100820097

OFFICE	DWMEP	DWMEP	DWMEP	DWMEP	DWMEP	DWMEP	DWMEP
NAME	NDevaser	ARidge	AWalker-Smith	MFuller	CMcKenney DEsh for CMcKenney (attached)	GSuber	PBubar
DATE	03/24/10	03/25/10	03/25/10	03/26/10	03/26/10	3/31/10	3/31/10

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Request for Additional Information for the 2009 Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site

March 2010

Structure of Comments

The U.S. Nuclear Regulatory Commission (NRC) staff's review comments are separated into the topics listed below to facilitate the U.S. Department of Energy's (DOE's) responses. DOE documents are referenced by number. Section or table references provided without an associated document title or reference refer to sections or tables in the "*Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site, SRR-CWDA-2009-00017*".

The path forward provided for each comment is one recommended approach to resolution; the NRC staff understands that there may be more than one method for adequately addressing the technical issues raised in the comments. Appropriate responses to some comments may depend on the nature of the resolution of other comments. It will be important for DOE to ensure internal consistency of the responses, especially if any changes are made to analyses supporting the PA.

Comment Topics

Performance Assessment Methods
Inventory
Infiltration and Erosion Control
Saltstone Performance
Vault Performance
Far-field transport
Air Pathway
Inadvertent Intrusion
Biosphere
ALARA analysis
Clarifying Questions

Performance Assessment Methods

PA-1 **Comment:** The contribution of individual radionuclides to the dose was not provided for several deterministic sensitivity cases.

Basis: It is important to know which radionuclides are contributing to the dose in order to understand which radionuclides are most risk significant and to understand which factors the dose is likely to be sensitive to. A thorough understanding of these factors is critical to performance monitoring.

Path Forward: Provide the doses from individual radionuclides for Case B, Case C, Case D, Case E, the synergistic case, and the case presented in Section 5.6.6.7 of the PA, and for any new analyses that are performed in response to other comments in this document.

PA-2 Comment: Probabilistic sensitivity analyses were not provided for cases representing bulk saltstone degradation.

Basis: Probabilistic sensitivity analyses were performed only for Cases A and C. Although Case C represents a fast flow pathway through saltstone, neither Case A nor Case C represents degradation of the bulk saltstone matrix. Case E, which represents saltstone degradation, was not included in the sensitivity analysis. Dose sensitivities in a case with degraded saltstone are expected to be different from the sensitivities in a case without degraded saltstone. For example, because chemical transitions would be achieved earlier in a case in which bulk saltstone has a greater hydraulic conductivity, parameters affecting the transport of radionuclides sensitive to pH transitions in saltstone may have a greater effect on dose. Similarly, parameters related to slower-moving radionuclides (e.g., plutonium) may have a more significant effect on dose in a case in which more water moves through the bulk saltstone. The sensitivity of these parameters is important to identifying issues that should be tracked during monitoring.

Path Forward: Provide a probabilistic sensitivity analysis for a case that reflects saltstone degradation, or explain why the sensitivity analyses performed in the PA are expected to reflect the sensitivities of dose in a case that reflects saltstone degradation. If a new sensitivity analysis is performed, it should be consistent with any modifications made in response to the comments in this document.

PA-3 Comment: The determination of key radionuclides described in Section 5.2.2 of the PA may not have captured all of the risk significant radionuclides. The determination of key radionuclides is significant to the results of the PA because many of the analyses used to support the PA only include the key radionuclides (e.g., the PORFLOW analyses for Cases B-E).

Basis: The determination of the key radionuclides was based on the all-pathways doses calculated for the Case A scenario. In this case, it is assumed that there is no degradation or fracturing of the saltstone, and, consequently, there is very little water passing through the saltstone. These assumptions may be optimistic and may not adequately represent the actual performance of the disposal system (see, e.g., Saltstone Performance comments). In the cases where degradation and fracturing of the saltstone occur, other radionuclides may also be important contributors to dose. For example, Table 5.6-15: "Most Sensitive Parameters for Endpoints of Interest – Case C" lists the K_d values for plutonium in clayey and sandy soils as being important parameters, which indicates that plutonium is an important radionuclide for Case C. Because Pu-238 happens to be a parent of the key radionuclide Ra-226, its transport was considered; however the process used in determining the key radionuclides (Section 5.2.2) did not identify this radionuclide, which indicates that the process may not be sufficient to capture all radionuclides that are potentially important to dose in reasonably foreseeable scenarios.

In addition, the response to other comments may affect the dose modeling results. It is important to consider if changes made to the model as part of the response to other comments results in a significant dose from additional radionuclides (e.g., a dose above the 0.05 mrem/yr criteria used in Section 5.2.2 of the PA).

Path Forward: Determine if any additional radionuclides are significant contributors to dose in cases other than Case A, and if so, add these radionuclides to the key radionuclide list and provide the dose results. Evaluate whether changes made to the model based on the responses to other comments in this document results in a significant dose from any additional radionuclides. If so, add these radionculides to the list of key radionuclides and provide the dose results.

PA-4 **Comment:** Benchmarking based only on key radionuclides identified in the base-case analysis does not provide adequate support for the interpretation of alternate-case GoldSim model results.

Basis: As discussed in Section 5.6.2 of the PA, benchmarking was performed only for radionuclides that were significant to dose in the base case. Because the base case assumed very little water flow through the disposal units and waste form, the key radionuclides identified in the base case are all relatively mobile in cementitious materials and soils.

The GoldSim model, which is not benchmarked for radionuclides important in other cases, may not represent transport of those radionuclides well. For example, divergence between the PORFLOW and GoldSim model results at 20,000 years is attributed to differences in plutonium transport (SRNL-TR-2009-00052).

An understanding of the applicability of the GoldSim model to less-mobile radionuclides is needed to support an interpretation of the results of the GoldSim model in alternate cases. For example, the peak of the mean dose for Case C in GoldSim within 20,000 years is 492 mrem/yr while in PORFLOW it is only 5.54 mrem/yr (SRR-CWDA-2009-00017). A better understanding of the applicability of the GoldSim model to less-mobile radionuclides would provide a better basis for determining how to interpret the GoldSim results.

Path Forward: Explain the applicability of the GoldSim model to radionuclides that are important in alternate cases but were not used in the benchmarking analysis, or provide benchmarking of the less mobile radionuclides.

PA-5 **Comment:** Additional information is needed about the benchmarking factors and other GoldSim parameter adjustments based on benchmarking to the PORFLOW model.

Basis: The benchmarking parameters described in the benchmarking summary (Section 5.6.2) of the PA include (1) the factors in Table 5.6-1, (2) adjustments to the K_d values for Tc, (3) the saturated zone flow rate, (4) a factor applied to saturated zone cells to account for "dilution" shown in PORFLOW (Section 5.6.2.3.2) (5) the plume correction factor, and (6) the contribution of Vaults 1 and 4 to unexpected regions (Section 5.6.2.3.2).

It is unclear whether this list is exhaustive or whether other benchmarking factors or other adjustments were applied to the GoldSim model. For example, Section 5.6.3.8.1 of the PA indicates that the thickness of the saturated zone and the development of its distribution were based, in part, on the results of the benchmarking process; however, it is unclear whether this adjustment corresponds to the factor applied to saturated zone cells listed in (4), above. Based on the summary in the PA, and the description in the "*Saltstone Disposition Facility Stochastic Transport and Fate Model Benchmarking*" (SRNL-TR-2009-00052), the meaning of benchmarking factor (4), and the reference to PORFLOW "dilution" in the description of benchmarking factor (4) is unclear. It also is not clear how benchmarking factor (4) was derived, what its value is, and to which parameter in the GoldSim model it is applied.

In addition, the physical basis for some of the benchmarking factors is not clear. For example, while a reasonable explanation is provided for the plume correction factor and contribution of Vaults 1 and 4 to unexpected regions in Section 5.6.2.3.2, no explanation is provided of the physical basis for the benchmarking factors provided in Table 5.6-1. In some cases, the factors in Table 5.6-1 adjust the flow by an order of magnitude. An adequate understanding of the benchmarking adjustments is important to understanding the basis for the GoldSim model and the resulting uncertainty analyses.

Path Forward: Provide a list of all benchmarking factors and any other parameter adjustments that were made based on benchmarking results for each case, including the final value of the factor or magnitude of the adjustment. Describe how each factor applies to the conceptual model (e.g., indicate whether the factor adjusts a flow rate, accounts for dispersion, or adjusts an aspect of the structural model such as the saturated zone thickness). Note the type of analysis used to calculate each benchmarking factor or parameter adjustment (e.g., benchmarking based on flux between the unsaturated and saturated zone or concentrations at 100 m). Provide a description of the meaning of benchmarking factor (4) in the basis of this comment. Provide an explanation of the physical basis of benchmarking factors that adjust the PORFLOW output by an order of magnitude or more.

PA-6 **Comment:** Results of analyses run to times beyond or far beyond the performance period appear to underestimate dose by excluding radionuclides and pathways based on their contribution to the base case analysis at 10,000 or 20,000 years. Although an estimate of the dose at extremely long times is not likely to be necessary for a compliance determination, it is important to understand the basis for any reported results and, when reporting the information, to note important limitations.

Basis: As discussed in Section 5.2.2, the selection of key radionuclides was based on the peak dose to a member of the public within 20,000 years in the base case. Because of the limited amount of water flowing through saltstone in the base case, the radionuclides causing an appreciable off-site dose within 20,000 years in the base case are all relatively mobile (i.e., Tc-99, I-129, Ra-226, Np-237, and Pa-231).

Section 5.5.1.5 indicates a peak dose associated with the key radionuclides is calculated through 40,000 years. However, it is not clear that it is appropriate to neglect the dose from less-mobile radionuclides that do not reach a member of the public within 20,000 years but may reach a member of the public within 40,000 years from the analysis. In addition, it is not clear if parents of the key radionuclides were included in the 40,000-year analysis.

Similarly, Section 5.6.4 reports doses from Case A run in GoldSim out to 450,000 years. Although an analysis of the dose at this very long time is not likely to be necessary for the demonstration of compliance in this case, it could cause confusion to report a dose that is a significant underestimate of the expected dose at very long times. Additional information would be necessary to evaluate whether the reported dose at 450,000 years is a reasonable estimate. For example, the parameters used in the flow and chemical models out to 450,000 years are not discussed. It appears the results reported for 450,000 years could be misinterpreted if the Case A flow parameters, which are based on the assumption that saltstone does not physically degrade, are not modified during the 450,000 year period. Furthermore, it is not clear if pathways and phenomena that were not considered in the base case or were determined to be insignificant contributors to dose in the base case at 10,000 years, but that may be more important at very long times (e.g., radon emanation, climate change, landform evolution) were included in the estimate of the dose at 450,000 years.

Path Forward: Revise the calculated dose at 40,000 years to reflect contributions from radionuclides that may have been transport-limited in the base case analysis but may reach a member of the public within 40,000 years. Provide the assumptions about the physical and chemical state of saltstone and the disposal units that were used in the 40,000 and 450,000 year analyses. Either explain how the reported dose in the 450,000 year analysis reported in Section 5.6.4 is expected to compare to the expected dose, considering potential doses from relevant radionuclides and pathways excluded from the analysis, or indicate that the 450,000 year dose should not be considered in the interpretation of results. The discussion of the 450,000 year analysis should clearly state limitations and assumptions.

<u>Inventory</u>

IN-1 **Comment:** The reported inventory of some of the radionuclides disposed of in Vaults 1 and 4 as of March 31, 2009 (X-CLC-Z-00027) exceeds the total inventory of these radionuclides assumed in the PA for these vaults (Tables 3.3-1 and 3.3-3 in the PA), even when accounting for the decay of these radionuclides to the year 2030.

Basis: As seen in the table below, the inventory provided in Table 3.3-1 of the PA for Am-241 in Vault 1 and the inventories provided in Table 3.3-3 for Ni-59 and Ra-226 is less than the reported inventory disposed of to date (as reported in X-CLC-Z-00027).

Table 1: Inventory Data for Selected Radionuclides

Radionuclide	Inventory in PA (decayed to 10/1/2030) (Ci)	Current SDF Inventory (as of 3/31/09) (Ci)	Current SDF Inventory (decayed 20 years) (Ci)
Vault 1			
Am-241	4.70E-04	5.83E-04	5.65E-04
Vault 4			
Ni-59	0.4	0.447	0.446
Ra-226	4.1	5.35	5.3

The calculation of the inventory in 2030 only accounted for decay and did not include ingrowth. Saltstone contains parent radionuclides for both Ra-226 and Am-241, so additional amounts of these radionuclides would ingrow over time.

Additionally, the PA states that the inventory was decayed to October 1, 2030, but the starting date of this calculation was not provided, so it is not clear exactly how many years of decay were assumed.

Path Forward: Provide the expected inventory for these radionuclides in Vaults 1 and 4. If the expected inventory is more than the inventory assumed in the PA, provide an updated estimate of the inventory of these radionuclides in Vaults 1 and 4 and the SDF decayed to October 1, 2030. Provide an assessment of the effect of the increased inventory on the dose. Provide the number of years of decay assumed in the inventory calculation.

IN-2 **Comment:** More information is needed about the basis for the uncertainty distributions for the radionuclide inventories used in the GoldSim calculations.

Basis: The derivation of the source inventory uncertainty distributions used in the GoldSim probabilistic analysis is described in Section 5.6.3.2 of the PA. These distributions represent the uncertainty associated with the ability of the WCS system to predict the inventories in the tank waste that will be disposed of at the SDF. Figure 5.6-32 of the PA presents the ratios of sample analysis results to predicted values for samples from 8 tanks for C-14, Cs-137, Pu-239, Sr-90, and U-238. Minimum and maximum values for the uncertainty distributions were selected based on the range of ratios observed in this figure. The distribution for radionuclides other than the five considered individually was assumed to have a minimum value of 0.1 and a maximum value of 10. However, the basis for this assumed distribution is not clear. It is also not clear why the assessment of the ratios of sample results to predicted values was only performed for the five radionuclides listed above and why the key radionuclides Ra-226 and Pa-231 and their parents were not considered in this assessment.

The uncertainty distributions were implemented in GoldSim using the truncated log-normal distribution. The geometric mean was assumed to be 1 and the distributions were truncated as described above. In addition, a value of 1.1 was used for the geometric standard deviation. The basis for the use of this standard deviation is not clear, and the use of such a small standard deviation does not seem to capture the variability shown in Figure 5.6-32 of the PA.

Path Forward: Provide more information regarding the basis for the uncertainty distributions assumed for the radionuclide inventories in the GoldSim calculations, particularly the geometric standard deviation used in the GoldSim model. Provide the basis for the assumed uncertainty distribution for the radionuclides not evaluated in Figure 5.6-32 of the PA.

IN-3 **Comment:** Information is needed on the process that will be used to ensure that the inventory will be distributed among the Future Disposal Cells (FDCs) in a configuration that provides reasonable assurance that the performance objectives will be met.

Basis: The total inventory for the SDF is estimated in Table 3.3-7 of the PA and the projected average inventory in the FDCs was provided in PA Table 3.3-5. The sequence in which the waste will be disposed, and consequently the amount of inventory that will be located in particular disposal cells, has not yet been determined. Based on the variability in the concentrations of the radionuclides in the various waste tanks in the tank farms, it is expected that the variability in the inventory from FDC to FDC could be significant.

The PORFLOW model used to demonstrate compliance with the performance objectives assumed that the inventory in each of the FDCs will be equal to the average inventory for all of the FDCs. In the probabilistic uncertainty analysis in GoldSim, the location uncertainty of the inventory was evaluated by randomly selecting the order in which the waste tanks would be emptied and the order in which the FDCs would be filled. Although the model simulates various disposal configurations, it is unclear if all configurations provide reasonable assurance of an acceptable dose. It appears that unfavorable configurations (i.e., configurations in which higher activity waste is placed into neighboring vaults) might result in an unacceptable dose. Without an understanding of the dose implications for the unfavorable configurations and a commitment that unfavorable configurations will not be implemented, the NRC will need to monitor to the assumption used in the PORFLOW calculations used to demonstrate compliance (i.e., that the FDCs all contain an inventory that is equal to the average FDC inventory provided in Table 3.3-5).

Path Forward: Provide information on the process that will be used to ensure that the placement of the different tank waste into the different FDCs is done in a way that provides reasonable assurance that the performance objectives will be met.

IN-4 **Comment:** More information is needed about the inventory expected to remain in the sheet drain systems for Vault 4 and the FDCs and the inventory expected to remain in the transfer lines at the time of closure.

Basis: Sections 3.2.1.2.5 and 3.2.1.3.5 of the PA state that after the operational period the drainwater collection system will be emptied and filled with grout. However, it is not clear if measures will be taken to clean the drainwater collection system and it is not clear how much inventory could remain in this system at the time of closure. If inventory remains in these systems at the time of closure, this inventory may be transported into the environment more rapidly than inventory in the saltstone wasteform because the sheet drain system is located at the edge of the vault and this system may provide a fast pathway into the environment. In addition, the inventory remaining in the sheet drains may be less encapsulated in the grout than the inventory in the saltstone. Information on the expected time of operation of the sheet drain system also was not provided. Thus, it is not clear how long the sheet drain systems will remain operational and when they will be grouted.

It is also not clear how much inventory could remain in the transfer lines at the time of closure. If inventory remains in the transfer lines, an intruder could inadvertently drill through the transfer lines or be exposed through other scenarios and receive a dose from this inventory.

Path Forward: Provide a description of the measures that will be taken to empty and clean the drainwater system and transfer lines, and provide an estimate for when the operation of the sheet drain system will stop and when it will be grouted. Provide an estimate of the inventory expected to remain in the sheet drain systems and transfer lines at the time of closure. If this inventory is not negligible, provide an estimate of the potential dose from this inventory that could result to an offsite member of the public and to an intruder who drills though a line or is exposed to the inventory in a transfer line by another pathway.

<u>Infiltration and Erosion Control</u>

IEC-1 **Comment:** The PA does not describe what portion of the water entering the perimeter drainage channel will infiltrate back into the native soil or backfill, or what, if any, effect such infiltration will have on vadose zone or saturated zone flow.

Basis: Until the HDPE/GCL layer in the closure cap is degraded, most of the precipitation infiltrating the cap will be diverted to the perimeter drainage channels as subflow through the drainage layer. Based on WSRC-STI-2008-00244, Section 4.4.17, the perimeter drainage channel appears to coincide with the “toe of side slope” in the PA, Figure 3.2-21. Focused infiltration along the perimeter drainage channels could alter the pattern of flow in the vadose zone, create local perched, saturated lenses, and/or flow back toward the disposal vaults. Divergence of natural percolation away from the closure cap footprint also could alter groundwater flow patterns in the saturated zone. Based on SRNL-STI-2009-00115, infiltration in the vadose zone models was specified based on simulated infiltration through the closure cap using the HELP model. The lower boundary condition in the vadose zone model was the water table based on the calibration of the GSA/PORFLOW model (SRNL-STI-2009-00115). Based on the model description in SRNL-STI-2009-00115, the vadose zone model simulations do not consider the effect of focused infiltration along the perimeter drainage channel outside

the footprint of the closure cap. The saturated zone model does not represent the effect of the closure cap on infiltration to the water table or focused infiltration from the perimeter drainage channel that might affect groundwater flow patterns or velocities (SRR-CWDA-2009-00017).

Path Forward: Provide a technical basis for neglecting the effect of focused infiltration along the perimeter drainage channels on flow in the vadose zone and flow in the saturated zone.

IEC-2 **Comment:** The cross-sections of disposal units in WSRC-STI-2008-00244 illustrate the lower backfill layer and other materials in the closure cap covering the cells, but do not indicate what materials will be used to backfill around the cells.

Basis: The cross-sections through the Saltstone Disposal Facility (Figures 6, 7 and 8 in WSRC-STI-2008-00244) indicate that some of the disposal cells (e.g., 6A/B, 12A/B) will be constructed below the preclosure grade. Photographs of the Saltstone Disposal Facility (e.g., SRNL-STI-2009-00115) show the disposal cells as free-standing structures suggesting that backfilling around the cells will be required prior to placing the lower backfill layer of the closure cap. The properties of backfill materials placed around the disposal cells will influence water movement and settlement in the vadose zone around the disposal cells. Illustrations showing the distribution of materials assigned to the computational grid in the vadose zone model (e.g., SRNL-STI-2009-00115, Figure 56) indicate that the backfill material will be same as that in the lower backfill layer.

Path Forward: Explain the nature and properties (e.g., hydraulic conductivity, porosity, bulk density) of the backfill material that will be placed around the disposal cells and the manner in which it will be placed and compacted.

IEC-3 **Comment:** Additional information is needed to support conclusions about the long-term performance of the side slopes of the closure cap.

Basis: The physical stability of the closure cap side slopes is important for the long-term stability and performance of the closure cap as a whole. WSRC-STI-2008-00244 discusses the following physical mechanisms that could degrade the closure cover:

- Static-loading induced settlement
- Seismic-induced liquefaction and subsequent settlement
- Seismic-induced slope instability
- Seismic-induced lateral spread
- Seismic-induced direct rupture due to faulting

The reference (WSRC-STI-2008-00244) concludes these phenomena will be unimportant to the stability of the SDF closure cover. In addition to the mechanisms discussed in WSRC-STI-2008-00244, the following mechanisms also could affect the closure cap side slopes:

- Slumping of the side slope
- Downslope creep of the riprap
- Vegetation growth on side slopes

Slumping and downslope creep of the riprap could expose the backfill underlying the side slope riprap leading to erosion of the side slope and ultimately the closure cap as a whole. 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, leading to slumping. Frost heave could also lead to downslope creep of the side slope riprap that would ultimately expose the underlying backfill to erosion. Although WSRC-STI-2008-00244 presents engineering calculations to support the sizing of riprap on the side slopes to resist the effects of erosion due to surface water runoff, no calculations are presented related to the stability of the side slope to slumping or the stability of the riprap to frost heave creep.

Modeling of the closure cap performance includes the effects of degradation due to pine tree propagation onto the vegetative cover, which is extensively discussed in WSRC-STI-2008-00244. Although the PA and supporting documents discuss the effects of vegetation on the performance of the closure cap, the possibility of vegetation developing on the side slopes of the closure cap is not addressed. Development of vegetation on the side slopes could have either a beneficial or deleterious effect on the slope performance and stability. For example, vegetation growth on the riprap on the side slopes and in the toe of the side slopes could reduce the ability of the side slope and perimeter drainage channel to conduct water away from the cover. Alternately, development of vegetation on the side slopes could be beneficial because development of vines or deep-rooted plants could stabilize the side slopes. On the other hand, windfall of trees on the side slopes could dislodge the riprap and expose the backfill to erosion. In particular, windfall due to extreme weather events can result in common-mode disruption that overtakes natural repair processes.

Although a barrier analysis discussed in the PA concluded that complete failure of the cap did not have a significant effect on dose, this conclusion is based on uncertain assumptions that ensure very limited water flow through the waste form (see, e.g., comments on Saltstone Performance in this document). Because of the importance of the hydraulic isolation of saltstone to long-term performance and because of the uncertainty in other factors limiting flow through saltstone during the 10,000 year performance period (e.g., limited degradation of the wasteform and disposal units), long-term performance of the cap as an erosion and infiltration barrier is considered an important element of establishing reasonable assurance that the performance objectives will be met.

Path Forward: Either provide a technical basis for neglecting side slope slumping and riprap creep as degradation mechanisms, or provide engineering calculations to demonstrate the resistance of the side slopes to these degradation mechanisms. Provide a technical basis for neglecting the effects of vegetation on the side slopes and toe of the side slopes, or provide an engineering assessment of the effects of vegetation on the stability and performance of the side slopes, toe of the side slopes, and closure cap as a whole. An assessment of the effects of vegetation on the side slopes and toe of the side slopes should be consistent with the response to comment IEC-4.

IEC-4 **Comment:** During the transition from Bahia grass to a pine tree forest the closure cap could be affected by external factors such as drought or fire, thus changing the assumptions required for the stability calculation.

Basis: The vegetative cover physical stability calculations based on the permissible velocity method presented in WSRC-STI-2008-00244 assume that the closure cap is vegetated with Bahia grass. Possible evolution of the vegetative cover after the period of institutional control is discussed in WSRC-STI-2008-00244 Section 6.2. The transition from a well-maintained Bahia grass cover to a mature pine forest covering the entire closure cap is estimated to take several hundred years. As the vegetation on the cap changes and is possibly impacted by fire or severe drought, the resistance of the cover to erosion may change (see, e.g., LA-UR-01-4658, 2001; PNNL-17859, 2008). The stability calculations presented in WSRC-STI-2008-00244 Appendix A assume that the closure cap has a Bahia grass vegetative cover yielding a maximum permissible runoff velocity of 3.22 feet per second. The calculated runoff velocity based on the probable maximum precipitation was 2.98 feet per second. The maximum permissible runoff velocity and calculated runoff velocity may be different if the cover is not well-maintained Bahia grass or the vegetation has been stressed by fire or drought.

As described in comment IEC-4, although the PA concluded that complete failure of the cap did not have a significant effect on dose, that conclusion is based on uncertain assumptions about the hydraulic performance of other elements of the disposal system. Thus, long-term performance of the cap as an erosion and infiltration barrier is considered an important element of establishing reasonable assurance that the performance objectives will be met.

Path Forward: Provide estimates of the vegetative cover physical stability to erosion based on the permissible velocity method for the cover conditions that may exist between the end of active maintenance and establishment of a mature pine tree or bamboo cover.

IEC-5 **Comment:** Differential settlement could occur due to the presence of the relatively rigid disposal cells within the lower backfill and non-uniform thickness of the backfill. This could affect the drainage efficiency of the upper drainage layer and the integrity of the geomembrane layer.

Basis: Static-loading-induced settlement is identified as a potential mechanism degrading the closure cap (Table 3.2-6 of the PA and WSRC-STI-2008-00244 Section 6.1). Settlement due to static loading is stated to be only a few inches and to be uniformly distributed over the closure cap.

The closure cap will be constructed over disposal cells and a lower backfill of nonuniform thickness. The disposal cells are concrete structures filled with saltstone that will be relatively rigid with respect to the backfill on which the closure cap is constructed. Based on cross sections in WSRC-STI-2008-00244, the combined thickness of the backfill and closure cap will vary from as little as 20 feet to as much as 60 feet across the Saltstone Disposal Facility. Settlement of the soil within the backfill between the disposal cells could be greater than that over the disposal cells. Such differential settlement could affect the local slope of the drainage layer and create stresses on the HDPE geomembrane.

Path Forward: Provide engineering calculations to justify the assumption that static-loading-induced settlement will only be a few inches and will be uniformly distributed over the closure cap.

IEC-6 **Comment:** Additional justification is needed for the hydraulic conductivity assigned to the foundation layer of the infiltration and erosion cap.

Basis: As described in WSRC-STI-2008-00244 Appendix I, the HDPE/GCL is treated as a combined layer in the HELP model with fully penetrating holes after a 300 year service life. According to the HELP model documentation (Schroeder et al., 1994), simulated flow through the holes in the HDPE/GCL combined layer is controlled by the size and number of holes, and the hydraulic conductivity and thickness of the underlying vertical percolation layer. The underlying layer is the foundation layer that is assigned a saturated, vertical hydraulic conductivity of 1×10^{-6} cm/s, but with other relevant hydraulic properties equal to those of SRS compacted backfill. The hydraulic properties of control compacted backfill are described in WSRC-STI-2008-00244, Section 5.4.2. A vertical, saturated hydraulic conductivity of 4.1×10^{-5} cm/s is assigned to this material. This value is 41 times greater than the vertical, saturated hydraulic conductivity assigned to the foundation layer in the HELP model. This lower value controls percolation through the closure cap as the HDPE/GCL layer degrades (develops more holes).

The technical basis for the hydraulic conductivity assigned to the foundation layer in the HELP model is not discussed, with the exception of the statement that bentonite will be incorporated into local soils used in the foundation layer (WSRC-STI-2008-00244). If a higher value of hydraulic conductivity was assigned to the foundation layer, the calculated percolation rate through the closure cap would be higher at earlier times, although it might not be significantly greater after the HDPE/GCL layer is fully degraded.

Path Forward: Clarify whether the hydraulic conductivity value of 1×10^{-6} cm/s is a specification for the saturated, vertical hydraulic conductivity of the foundation layer in the future cap design or whether there is a technical basis for selecting this value for use in the HELP model. Provide any existing technical basis for the value assigned to the hydraulic conductivity of the foundation layer in the HELP model.

Saltstone Performance

SP-1 Comment: Additional justification is required for the assumption that saltstone is hydraulically undegraded for 20,000 years.

Basis: Section 4.2.3.2.4 of the PA indicates that, in the base case, degradation of the saltstone material is not assumed to occur during the performance period. The same section of the PA also acknowledges that the potential for physical degradation of the saltstone is uncertain. The assumption that saltstone will not degrade during the performance period appears to be based on the conclusion of "*Thermodynamic and Mass Balance Analysis of Expansive Phase Precipitation in Saltstone*" (WSRC-STI-2008-00236) that fracturing due to expansive phase precipitation is unlikely to occur in saltstone because the maximum amount of porosity filled is 34 percent. However, the PA does not provide a basis for neglecting other types of degradation, such as shrinkage cracking, corrosion cracking, or dissolution of salts and low solubility matrix phases. Furthermore, DOE deferred responses to several NRC comments on the expansive phase precipitation report (NRC, 2009a), and characterized the report as preliminary research (SRR-CWDA-2009-00011). NRC acknowledged that the report was an initial step in a research program but cautioned that the use of research as support for assumptions and parameters in performance assessments should be consistent with the maturity of the research (NRC, 2009a).

Because of the preliminary nature of the expansive phase precipitation report and the potential for other types of degradation, additional support is needed for the assumption that saltstone remains undegraded in the base case during the performance period (and in calculations carried to 20,000 years). NRC comments on the expansive phase report to which DOE deferred a response include the following:

1) The conclusions of the expansive phase precipitation report are based on geochemical modeling results. It is unclear whether there are data and observations available for comparison to constrain the modeling calculations.

2) The expansive phase study does not consider the effects of organic additives or pozzolanic replacement on the dissolution and precipitation of cement-related compounds, which may have an effect on the generation of expansive phases. Future research could consider the effect that sulfide from the blast furnace slag might have on the phases and reactions present in this system.

3) Experiments that are designed to collect data on initial mineralogical conditions, fundamental thermodynamic data and reaction kinetics would provide much needed

model support for this study.

4) Geochemist's Workbench is based on an equilibrium reaction model. However, reaction kinetics could result in metastable products that are often associated with an increase in volume. Subsequent studies might consider expansive phases produced by intermediate or metastable reaction products.

5) The conclusions reached in this study area could be integrated with other ongoing or recently completed studies. Dixon (SRNL-STI-2008-00421) recently completed a study on the physical properties of grout, which included bulk porosity measurements. Updated measurements of the bulk porosity of saltstone grout may be useful in assessing whether expansive phase precipitation is likely to result in grout degradation.

In addition to expansive phase precipitation, additional mechanisms could cause degradation of saltstone. Degradation mechanisms that may cause discrete fracturing along certain features of the wasteform, such as corrosion cracking along reinforcement bars or shrinkage cracking around the wasteform perimeter or support columns, are addressed non-mechanistically in the PA by sensitivity cases B-D and the synergistic case, which postulate fractures through the waste. Mechanisms that may cause a network of smaller-scale cracking, such as dissolution of salts or low-solubility matrix phases, are addressed non-mechanistically in sensitivity Case E and in an increased saltstone hydraulic conductivity case discussed in Section 5.6.6.7. However, as discussed in SP-3, SP-4, SP-5, and SP-6, the degree of conservatism of these cases is unclear. Furthermore, because the base case result is an important factor in the compliance determination, it is important to be able to support assumptions about saltstone degradation used in the base case. For these reasons, additional support is needed for the assumption that saltstone does not degrade hydraulically in the base case.

Path Forward: Provide additional basis for assuming no hydraulic degradation of saltstone occurs in the base case or provide an updated base case analysis that reflects estimated saltstone hydraulic degradation (e.g., changes in hydraulic conductivity and effective diffusivity). Specifically, address the specific comments on the expansive phase report included in the basis, additional degradation mechanisms noted in the basis, and any other relevant degradation mechanisms that could cause hydraulic degradation of saltstone. If a new analysis is provided, the assumptions should be consistent with the response to other comments in this document.

SP-2 **Comment:** A basis is required for the modeled extent of saltstone fracturing.

Basis: As described in SP-1, various mechanisms may cause degradation of cementitious waste forms. Fracturing is addressed non-mechanistically in the PA by Cases B, C, and D. However, the relationship between the total fracture area and fracture geometry assumed in Case C and the total fracture area and geometry that may occur in various plausible degradation cases is not clear. For example, it is not clear if the total fracture area represented in Case C adequately represents the fracturing that could occur due to the degradation mechanisms discussed in SP-1.

Once fracturing is initiated, increased water infiltration can increase the rate of subsequent degradation. For example, increased infiltration through the wasteform can speed dissolution of low-solubility phases or increase the rate of introduction of species that could form expansive precipitates, such as sulfates. As fracturing occurs, the volume-to-surface-area of saltstone blocks between fractures would increase, decreasing the diffusive length required for radionuclides to travel from the wasteform. In addition, as the volume-to-surface-area of blocks between fractures increases, the rate of leaching could increase, increasing the rate of subsequent fracturing.

Although fracturing is represented in the PA as a low-probability case, initial fracturing of saltstone has been observed (see, e.g., SRNL-ESB-2008-00017).

Path Forward: Provide a basis for the extent of fracturing assumed to occur in Case C. Address the potential acceleration of fracturing that could occur as the average volume-to-surface-area ratio of intact saltstone blocks decreases. Address the mechanisms noted in the basis as well as other mechanisms by which fractures could increase the rate of subsequent fracturing. Alternately, provide a new estimate of saltstone fracturing during the performance period, including a basis for the new estimate, and the effect of the new estimate on dose.

SP-3 **Comment:** The moisture characteristic curve for intact saltstone implemented in the PORFLOW model does not sufficiently account for experimental uncertainties and is inconsistent with literature results for material similar to saltstone and other cementitious materials.

Basis: The PA relies on moisture characteristic curves to determine the flow through unsaturated cementitious materials. Because direct measurements of unsaturated hydraulic conductivity were considered to be time and cost prohibitive, the SRS report, "*Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes"* (SRNL-STI-2008-00421) relied on theoretical and indirect methods to predict the unsaturated hydraulic conductivity based on measurements of saltstone samples for a suction range of 0 to 55 bars. A monitoring follow-up item related to characteristic curve uncertainty (ML091320439-012) was closed based on the DOE conclusion that the saltstone remained sufficiently close to saturation that the shape of the characteristic curves was not risk-significant (NRC, 2009b). However, even in the small range of saturations considered in the PA (i.e., a minimum of 98% saturation for saltstone), the characteristic curves used for saltstone predict significantly reduced unsaturated hydraulic conductivities as compared to saturated hydraulic conductivities (see Figure 1, below).

The PA implements curves substantially different from those found in literature. For example, the curves in the PA are significantly different from the curves discussed in "*Hydraulic Property Data Package for the E-Area and Z-Area Soils, Cementitious Materials, and Waste Zones*" (WSRC-STI-2006-00198) (Figure 1). The moisture characteristic curves discussed in WSRC-STI-2006-00198, which were derived by Rockhold et al. (1993), Savage and Janssen (1997), and Baroghel-Bouny (1999) for different cementitious materials by different methods, all have very similar characteristics. The similarity of the curves is significant because the curve derived by

Rockhold et al. (1993) was based on a Hanford double-shell slurry feed (DSSF) grout formulation that is very similar to saltstone (WSRC-STI-2006-00198). Both saltstone and the DSSF grout consist of approximately 47% blast furnace slag, 47% fly ash, and 6% Portland cement with similar salt concentrations (WSRC-STI-2006-00198).

Difficulties with experimental methods introduced additional uncertainty into the characteristic curve for saltstone implemented in the PA. The curve developed in "*Numerical Flow and Transport Simulations Supporting the Saltstone Disposal Facility Performance Assessment"* (SRNL-STI-2009-00115) is based on experiments conducted at the Idaho National Laboratory (INL) which experienced experimental challenges that are not typically encountered in traditional soil and rock testing, as discussed in "*Hydraulic and Physical Properties of MCU Saltstone"* (WSRC-STI-2007-00649). These challenges resulted in the following non-standard conditions which introduce uncertainty into the results: (i) modification of standard tests, (ii) inconsistent sample preparation, (iii) hydraulic analyses being obscured by the generation of gas within the saltstone samples, (iv) inability to meet the requirements of minimizing the effects of the matrix potential gradient for the samples, (v) limited drainage of the samples, and (vi) the assumption of a residual moisture retention value in the samples that is in contrast with the literature (WSRC-STI-2006-00198; Vanapalli, 1998).

Case E and the increased hydraulic conductivity case discussed in Section 5.6.6.7 address the uncertainty in flow through saltstone by assuming it the bulk saltstone to be degraded. Cases B-D and the synergistic case address uncertainty in the flow through saltstone by assuming saltstone to be fractured. However, due to the uncertainty in the characteristic curves for intact saltstone and fractured saltstone, as discussed in this comment and comment SP-4, it is not clear how conservative these sensitivity cases are. In addition, because the base case result is an important factor for compliance determination, it is important to be able to support assumptions about the characteristic curves used for the base case.

Path Forward: Provide additional justification for the moisture characteristic curve for intact saltstone implemented in the PA model by addressing the experimental sources of uncertainty described in the basis. Alternately, provide updated results of Cases A, B, C, D, the synergistic case, and the sensitivity case in Section 5.6.6.7 that use a characteristic curve for intact saltstone that is more consistent with results in the literature. Any updated analysis should be consistent with the response to SP-4.

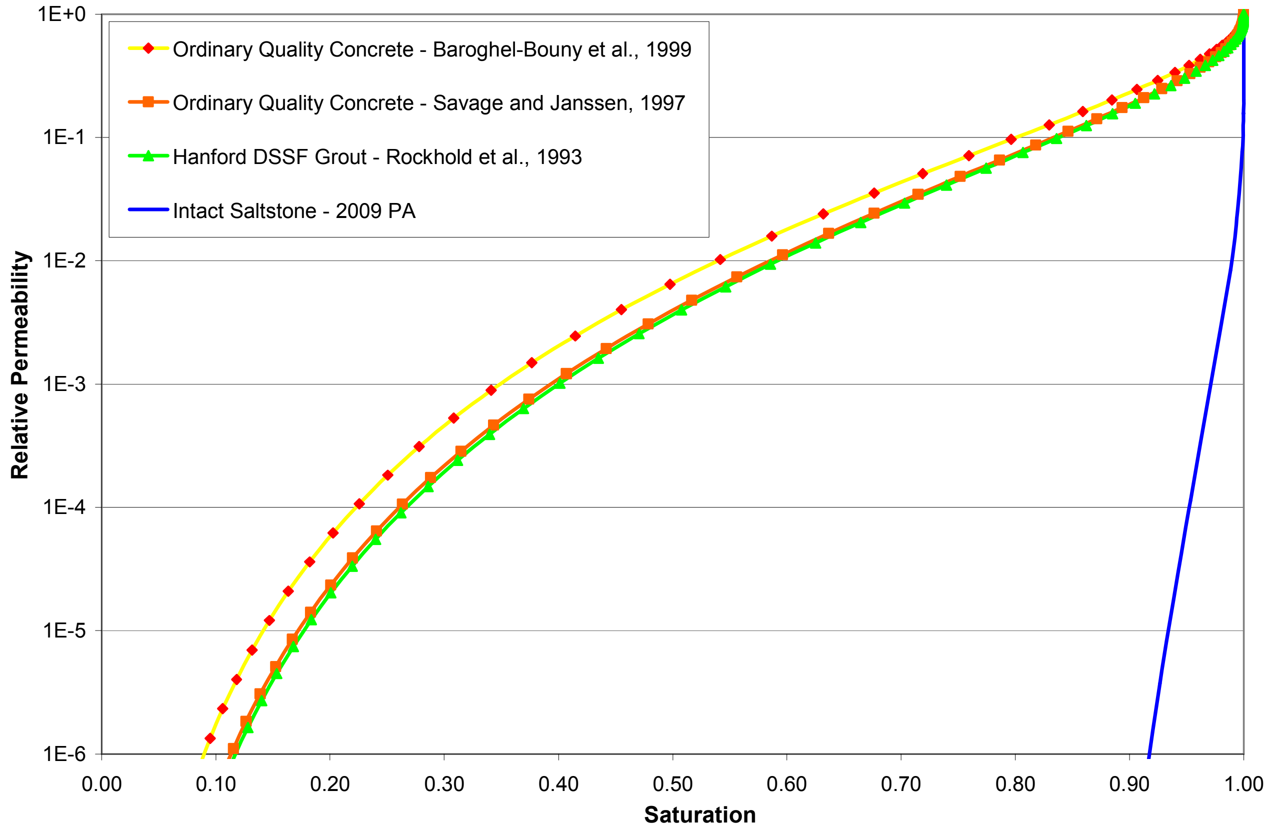

Figure 1: Moisture characteristic curves adapted from the PA and WSRC-STI-2006-00198

SP-4 **Comment:** Characteristic curves implemented in the PA are based on a continuum approach that does not reflect non-equilibrium flow.

Basis: The characteristic curves developed by INL (referred to in SP-3) were also used as the basis for the fractured saltstone and concrete characteristic curves (see Figure 2 below) that were developed in "*Numerical Flow and Transport Simulations Supporting the Saltstone Disposal Facility Performance Assessment"* (SRNL-STI-2009-00115). The authors discuss the use of an analytical approach developed by Or and Tuller (2000) to adapt INL moisture characteristic curves for cracked cementitious materials because experimental characteristic data for cracked vault concrete and saltstone grout are not available (SRNL-STI-2009-00115). However, use of moisture characteristic curves combined with coarse spatial and temporal averaging can result in an inadequate representation of non-equilibrium flow.

Path Forward: Provide additional support for the modeled flow through fractures. Model support could include field observations and laboratory experiments that verify consistency between numerical results and physical measurements.

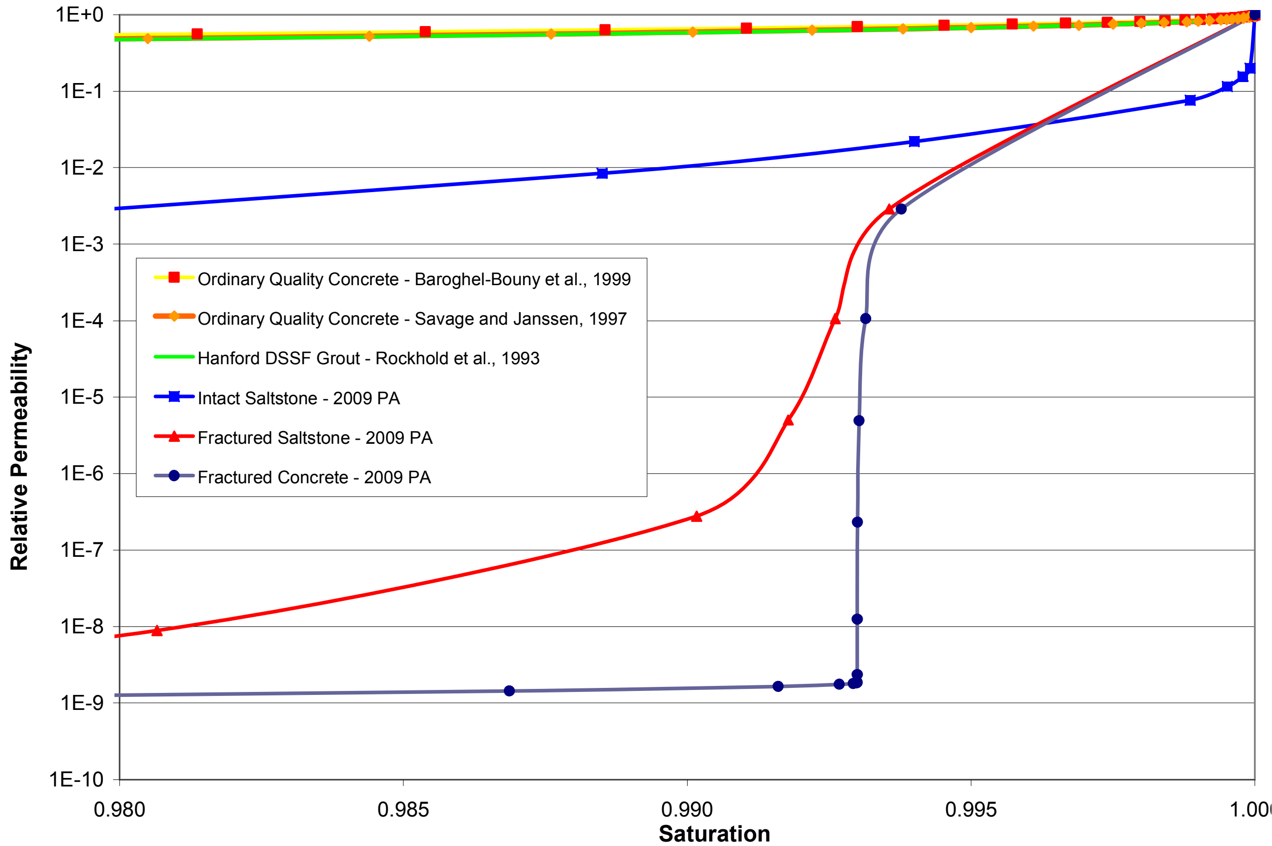

Figure 2: Characteristic curves for the intact and fractured saltstone and concrete as adapted from the 2009 PA and SRNL-STI-2009-00115

SP-5 **Comment:** Additional support is needed for the hydraulic conductivity of intact saltstone that is used in Case A, Case B, Case C, Case D and the synergistic case.

Basis: In response to NRC Issue 2007-1, (NRC, 2008) DOE is in the process of completing an analysis of saltstone core samples to determine the hydraulic properties of as-emplaced saltstone grout, as described in "*NRC Salt Waste Monitoring Open Item Status*" (SRR-CWDA-2010-00009). However, because of the sensitivity of SDF performance to hydraulic properties of saltstone grout, additional information is needed to support the review of the updated PA prior to the completion of DOE's analysis of saltstone core samples.

The hydraulic conductivity value in the PA for intact saltstone is 2.0E-9 cm/s for Case A, Case B, Case C, Case D and the synergistic case. This value represents the recommended value for saltstone samples made from SWPF treated waste (SRNL-STI-2008-00421). Because this value represents a best estimate based on laboratory measurements of simulated samples (rather than as-emplaced saltstone), these results may not accurately reflect the hydraulic conductivity of as-emplaced saltstone. Until the testing program described in SRR-CWDA-2010-00009 is complete, a more conservative

assumption may be required to account for these differences.

The hydraulic conductivity of as-emplaced saltstone may not be well represented by the hydraulic conductivity of small laboratory-prepared samples because laboratory measurements on samples that are small relative to the field scale are unlikely to capture the heterogeneities that tend to dominate hydraulic properties. In addition, variations in field placement, consolidation, and curing conditions that are discussed in the SRS report on "*Hydraulic Property Data Package for the E-Area and Z-Area Soils, Cementitious Materials, and Waste Zones*" (WSRC-STI-2006-00198) can result in cementitious materials that vary by several orders of magnitude in hydraulic conductivity. A hydraulic conductivity value that is derived from laboratory samples may result in a value that varies significantly from as-emplaced conditions.

In addition to the difficulty in scaling results from a laboratory-prepared sample to a large field-scale wasteform, experimental and analytical uncertainties involved in the measurement of hydraulic conductivity should be addressed in the basis for a hydraulic conductivity value used in modeling. For example, the hydraulic testing used as a basis for the hydraulic conductivity value used in SRS's PA model (SRNL-STI-2008-00421) does not discuss the potential reactions of $Ca(OH)_2$ with CO_2. As stated in the report, "*Hydraulic and Physical Properties of MCU Saltstone*" (WSRC-STI-2007-00649), the high pH of the saltstone permeant promotes the rapid dissolution of atmospheric CO_2, which readily reacts with $Ca(OH)_2$ to precipitate $CaCO_3$. The formation of $CaCO_3$ would significantly and perhaps artificially decrease the hydraulic conductivity of cementitious materials. Although this concern was discussed in WSRC-STI-2007-00649 for MCU samples, the hydraulic tests that form the basis for the hydraulic conductivity value used in the PA model (SRNL-STI-2008-00421) do not seem to have been conducted in a CO_2-free atmosphere, which could lead to the underestimation of hydraulic conductivity.

In addition, a monitoring follow-up item (ML091320439-11) is open on the impact of varying pore solution concentration on the measured hydraulic conductivity of certain simulated samples, including the samples used as the basis for the hydraulic conductivity value used in the PA (SRNL-STI-2008-00421). In response to NRC's comment, report SRR-CWDA-2009-00009 stated that simulants were adjusted based on geochemical modeling to preclude the formation of any precipitates that would artificially lower the hydraulic conductivity SRS. In addition to the potential impacts of precipitates, there are potential impacts of the varying pore solution concentration on hydraulic conductivity. As the salt concentration in the pore water decreases with time, the permeability may increase due to changes in permeant viscosity and density caused by the significant change in salt concentration.

A second monitoring follow-up item (ML091320439-13) is currently open regarding logarithmic averaging of hydraulic conductivities of saltstone samples used as the basis for the value used in the PA (SRNL-STI-2008-00421). In response to NRC's comment, SRS discussed the basis for logarithmic averaging for skewed distributions in general (SRR-CWDA-2009-00009). However, the specific concern remains that insufficient data were collected to determine the distribution for hydraulic conductivity as hydraulic tests were only conducted on three samples. Although potential outliers may bias the data, the use of logarithmic averaging over a limited data set may not be conservative.

Although the potential for increased hydraulic conductivity is addressed non-mechanistically in the PA by sensitivity Case E and the increased hydraulic conductivity case in Section 5.6.6.7, as discussed in other comments in this section (Saltstone Performance), the conservatism of these cases is not clear. In addition, because the base case result is an important factor in compliance determination, it is important for the assumptions regarding the hydraulic conductivity used in the base case to be well supported. Accordingly, additional support is needed for the hydraulic conductivity value that was implemented in the PA for the base case.

Path Forward: Provide additional support for the hydraulic conductivity value that is implemented in the PA for intact saltstone. Additional support should include a description of how data from laboratory samples is scaled to represent full-scale, as-emplaced saltstone. Additional support should also address the specific analytical concerns raised in the basis of this comment, including the potential impact of atmospheric CO_2 on the results. Demonstrate that analyses for intact saltstone saturated hydraulic conductivity are valid over the range of pore water concentrations expected to occur over the 10,000 year compliance period. Provide justification for the logarithmic averaging of hydraulic conductivity for a limited data set or provide additional data to characterize the distribution. Alternatively, provide an updated base case analysis that uses a hydraulic conductivity value that is well supported.

SP-6 **Comment:** Additional basis is required for the values of the effective diffusivity of intact and degraded saltstone used in the base case and sensitivity cases.

Basis: As discussed in comment SP-1, the effects of degradation of bulk saltstone (as compared to fractures in otherwise intact saltstone) are addressed in sensitivity Case E, in the synergistic case discussed in Section 5.6.6.5, and in an increased saltstone hydraulic conductivity case discussed in Section 5.6.6.7. In each of these cases, the hydraulic conductivity of saltstone is adjusted, but the effective diffusivity is kept constant at the base-case value. Because both the effective diffusion coefficient and hydraulic conductivity are intimately related to pore structure in cementitious materials, it is reasonable to expect that both coefficients would increase as saltstone degrades. The basis for adjusting the hydraulic conductivity in the sensitivity cases but maintaining the effective diffusivity at the base-case value does not appear to be addressed in the PA.

In addition, clarification is needed of the basis for the effective diffusivity of intact saltstone. The supporting document "*Numerical Flow and Transport Simulations Supporting the Saltstone Disposal Facility Performance Assessment*" (SRNL-STI-2009-00115) indicates that the effective diffusivity is based on a comparison to other cementitious materials with similar hydraulic conductivities, but the specific materials used for comparison and the process by which an effective diffusivity value was selected are not provided. Table 4.4-16 of the PA indicates that the effective diffusion coefficient is based on the effective diffusion coefficient of high quality concrete in the supporting document "*Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes*" (WSRC-STI-2006-00198). However, the actual value of the effective diffusion coefficient for high quality concretes provided in Tables 6-44 and 6-47 of WSRC-STI-2006-00198 is 5 E-8 cm^2/s, which does not match the value of 1.0 E-7 cm^2/s used in the PA for

saltstone. Furthermore, it is not clear why an effective diffusivity value appropriate for high quality concrete, which has a porosity of 0.11 (PA Table 4.2-16) would be appropriate for saltstone, which has a porosity of 0.58 (PA Table 4.2-16). While the choice of an effective diffusion coefficient of 1.0 E-7 cm^2/s is more pessimistic than the value provided for high quality concrete in the supporting document, the basis for the effective diffusivity value chosen should be clarified.

Path Forward: Provide a basis for using the effective diffusivity of intact saltstone in the two sensitivity cases that address degraded saltstone listed in the basis or update the sensitivity cases that address degraded saltstone with a value of effective diffusivity that reflects the physical degradation of the wasteform. Clarify the basis for the value of the effective diffusivity of intact saltstone.

SP-7 **Comment:** Additional bases are needed for key assumptions used in the simulation of sulfate attack with the STADIUM code.

Basis: SRS modeled the degradation of Vault 1and 4 and FDC concretes due to sulfate attack using the STADIUM code. The STADIUM input parameters included the initial mineralogy, which was derived using the Samson and Marchand (2007) mass balance method that was developed for ordinary Portland cement. In SRNS-STI-2008-0050, the initial grout mineralogy for the Vault 1 and 4 surrogate and FDC surrogate was calculated using a mass balance, assuming the initial paste is made of portlandite, CSH, monosulfates, and ettringite. However, in Samson and Marchand (2007), the calculation method was applied to hydrated paste prepared from ordinary Canadian Type 10 Portland cement. The initial mineralogy for blended cements (Portland cement mixed with fly ash, silica fume, and blast furnace slag) is different from that of Portland cement, and the degree of sulfate attack also could be different. It is not evident that the mass balance method applies to blended cements. If it does not, the results of the sulfate attack calculations could change.

The STADIUM model also relies on assumptions about CSH phase solubility. The SIMCO sulfate attack model used a simplified approach to represent the CSH phase solubility, in which the Ca/Si ratio was kept constant at 1. The approach is simpler than that of Berner (1988), who represented the CSH solid solution using different model solids for different Ca/Si ratios of 0, 0 to 1, 1 to 2.5, and >2.5. The approach used by SIMCO was validated for sulfate attack cases by Samson and Marchand (2007) and Maltais et al. (2004). However, the validation cases used Portland cements, not blended cements that are to be used for the future disposal cells. During a review of the sulfate attack model, the NRC staff questioned the use of this approach to CSH solubility (NRC, 2009). In response (SRR-CWDA-2009-00010), SRS indicated that the approach had been validated for high alkaline and high pH conditions by Henocq et al. (2007). Because this reference was not available at the web address SRS provided, it is not clear if the validation performed by Henocq et al. (2007) was based on Portland cements or blended cements similar to those that are to be used for the future disposal cells. Because of the coupled processes involved in sulfate attack, it is not evident how a more detailed model for CSH would change the results of the sulfate attack analysis.

During the review of the sulfate attack model, the NRC staff also questioned basis for neglecting minor species such as AlO_2^-, Fe^{3+}, SiO_3^{2-}, CO_3^{2-}, and PO_4^{3}- (NRC, 2009a). In response, SRS indicated that minor species are not expected to significantly influence sulfate attack in particular or the evolution of the concrete matrix in general (SRR-CWDA-2009-00010). SRS explained that speciation of cement components such as calcium or silica are dependent on pH and that, at high pH, the concentrations of various species would be low (SRR-CWDA-2009-00010). However, the explanation did not provide a basis for concluding the concentrations would be low enough to be neglected. Because of coupled processes involved in sulfate attack, it is not evident how inclusion of these species would affect the sulfate attack analysis. Inclusion of CO_3^{2-} (due to ingress of CO_2 dissolved in groundwater or present in air) could result in the formation of $CaCO_3$, which also could reduce the tendency to form ettringite (and gypsum) by reducing the available Ca^{2+} in solution. On the other hand, CO_2 ingress would reduce the concrete pore water pH, which could depassivate the steel components and cause corrosion-induced cracking of the concrete.

Path Forward: Provide additional bases for the sulfate attack model, addressing the points described in the basis of this comment. Specifically, provide a basis for applying the Samson and Marchand (2007) calculation method to determine the initial methodology blended cements. Additional information could include a comparison of the calculated mineralogy of hydrated blended cements with phase composition derived using x-ray diffraction or other measurements.

Provide a basis for applying the simplified Berner (1988) approach to determining the solubility of CSH, including a basis for assuming that the approach can be applied to blended cements representative of those that are to be used for the future disposal cells (i.e., grout formulations including fly ash, silica fume, and blast furnace slag). Provide a basis for neglecting minor species, including AlO_2^-, Fe^{3+}, SiO_3^{2-}, CO_3^{2-}, and PO_4^{3}-.

SP-8 **Comment:** The initial grout mineralogy used in evaluating expansive phase precipitation is inconsistent with the initial mineralogy used to determine Eh and pH transitions in pore fluids. Depending on which initial mineralogy is more appropriate, the conclusions of either report could change.

Basis: WSRC-STI-2008-00236 and SRNL-TR-2008-00283 address expansive phase precipitation in saltstone and the Eh and pH transitions in pore fluids, respectively. In both reports, normative calculations were done to estimate the initial mineralogy of saltstone and concrete. However, in WSRC-STI-2008-00236, the saltstone initial mineralogy comprised CSH, hydrotalcite, gibbsite, quartz, hematite, and gypsum; the concrete initial mineralogy comprised CSH, hydrogarnet, ettringite, and portlandite. On the other hand, in SRNL-TR-2008-00283, the saltstone initial mineralogy comprised CSH, hydrotalcite, kaolinite, quartz, hematite, gypsum, and pyrrhotite; the concrete mineralogy comprised CSH, hydrotalcite, gibbsite, quartz, hematite, gypsum, and pyrrhotite. In addition, the initial mineralogies in the two reports are inconsistent with that in SRNS-STI-2008-00050, which used a different normative method. Using a different initial mineralogy could result in a different conclusion regarding the likelihood of expansive phase formation or the calculated pore volumes for Eh and pH transitions.

Path Forward: Provide a basis for using different initial mineralogies in the calculations described in the basis of this comment, or provide information that demonstrates the calculation results are not significantly affected by the differences in initial mineralogy.

SP-9 **Comment:** Uncertainty in groundwater composition was not considered in the Geochemist's Workbench simulations to estimate Eh and pH transitions in pore fluids.

Basis: Supporting reference SRNL-TR-2008-00283 indicates that the groundwater composition used in all the simulations of Eh and pH evolution is based on an analysis of a sample from a water table monitoring well in the vicinity of the Saltstone facility reported in WSRC-RP-92-450. The referenced report tabulates numerous groundwater compositions, and the basis for selecting the specific groundwater composition for the Geochemist's Workbench simulations is not evident. Furthermore, it is not clear whether a water sample taken from the water table aquifer would be representative of water chemistry in the unsaturated zone.

Path Forward: Clarify the basis for the selected groundwater composition used in SRNL-TR-2008-00283, addressing how well it represents the chemistry of water in the unsaturated zone. Alternately, provide information showing the effect of variation in SRS groundwater composition on the Eh and pH transitions, including any expected differences between the chemistry of the water samples addressed in WSRC-RP-92-450 and water in the unsaturated zone, is bounded by the estimated ±50 percent uncertainty in Eh and pH transition pore volumes. Provide reference WSRC-RP-92-450.

SP-10 **Comment:** There are indications that some measured plutonium and neptunium sorption coefficients in cementitious materials could reflect solubility rather than sorption, which could lead to a significant overestimate of plutonium and neptunium sorption.

Basis: The PA radionuclide release model uses K_d values to simulate the release of radionuclides from the saltstone waste form. A recent DOE-sponsored saltstone and concrete sorption study found that dissolved plutonium and neptunium concentrations were actually controlled by solubility during experiments originally thought to measure sorption (SRNL-STI-2009-00636). If a dissolved concentration in a sorption experiment is controlled to the solubility limit, the apparent K_d calculated from the experiment will be an overestimate. It is not clear from the sorption studies forming the basis for the K_d values for plutonium and neptunium used in the PA (WSRC-STI-2007-00640, SRNS-STI-2008-00045, and SRNL-TR-2009-00019) whether solubility effects had been ruled out. The use of K_d values based on sorption experiments in which solubility was actually the controlling process could lead to underestimates of radionuclide release rates.

Path Forward: Provide a basis for concluding that the K_d values for plutonium and neptunium used in the PA were not influenced by solubility limits during the sorption experiments used as a basis for the values, or analyze the effects of using alternate (non-solubility limited) K_d values on the performance assessment results.

SP-11 Comment: In recent experiments used to help define K_d values for cementitious materials, the distinction between "middle" and "old" age conditions was based chiefly on water chemistry—not on the mineralogical assemblage. It is not clear whether the differences in solid phases for the different stages can be neglected.

Basis: Recent SRS experiments (SRNS-STI-2008-00045) studied sorption coefficients for middle- and old-aged cementitious materials by using aqueous solutions equilibrated with portlandite and calcite, respectively. The two sets of experiments used essentially the same solid phase assemblages, whether fresh concrete or saltstone, or partially oxidized saltstone. This approach neglects the potential differences in mineralogical assemblage under the two sets of conditions. For old materials (i.e., Region III of Bradbury and Sarott, 1995), no portlandite is present and CSH phases continually decline in favor of other minerals (e.g., quartz and calcite). This transition could lead to less sorptive minerals and lower available surface areas for sorption.

Path Forward: Comment on the potential effect of mineralogical changes on K_d values as the concretes and saltstone transition from middle to old age, and whether neglecting the potential effects of mineralogical differences on K_d values could have led to underestimates of radionuclide release rates.

SP-12 Comment: Model support is needed for the process models supporting PA predictions of Eh–pH evolution for cementitious materials.

Basis: In the report SRNL-TR-2008-00283, SRS developed a geochemical model for transitions in Eh and pH in pore waters of concrete and saltstone using Geochemist's Workbench. The calculated pore volumes required for the transitions were used directly in the PA to establish appropriate K_d values for radionuclide release. The calculations were used, for example, as a basis for the conclusion that saltstone will remain reducing and middle-aged throughout the period of performance. This model is subject to uncertainties discussed in the report and others not discussed (e.g., mineralogical assemblage). The model results have not been validated by any objective comparisons to data or other information independent of model development.

Path Forward: Provide model support for the Geochemist's Workbench results regarding pore fluid volumes necessary for transitions in Eh and pH of pore fluids in cementitious materials (SRNL-TR-2008-00283). For example, model support could include a comparison of model results with the results of pH and Eh measurements in accelerated physical testing using higher flow rates than anticipated in full-scale saltstone.

SP-13 Comment: The effect of limiting the shrinking-core model to the effects of the Eh evolution of saltstone on Tc should be analyzed.

Basis: A shrinking-core model was used to calculate the K_d value for release and transport of technetium from individual model cells. This approach represents an enhancement in the PA treatment of release and transport. The shrinking-core model, however, does not track pH, which also affects release and transport by way of pH-dependent K_d values. As shown in Table 4.2-18, many elements experience significantly

less sorption in old age grout, which may appear near fractures and edges of the saltstone wasteform, than they do in middle-age grout. The shrinking-core model also is not used to model the release of other contaminants that may show Eh dependence (e.g., neptunium and uranium). Instead, K_d values for elements other than technetium are selected based on calculated step changes in the system Eh and pH.

In general, a shrinking-core model would be expected to predict a more gradual release of radionuclides than a step-change model and, therefore, predict a lower peak dose. However, because saltstone is predicted in the base case to remain reducing middle-age grout for the entire performance period and beyond 30,000 years (Table 4.2-17), the release of some redox and pH sensitive elements may be underestimated in the base-case analysis.

Path Forward: Discuss the basis for and effects of limiting the shrinking core model to technetium and Eh only, to the exclusion of pH and other elements.

SP-14 Comment: Additional information is needed about the basis for the K_d values used for iodine and radium in cementitious materials.

Basis: The most recent report on SRS sorption studies of cementitious materials shows that a number of measurements of iodine sorption for “old” materials (i.e., equilibrated with a calcite-saturated solution) yielded negative values, indicating essentially no sorption (SRNS-STI-2008-00045, Tables 2 and 3). That report and the PA, however, retained a previously recommended K_d of 4 mL/g for iodine. If iodine does not effectively adsorb to cementitious materials under old oxidizing conditions, the use of this nonzero value could lead to underestimation of iodine release rates. (This comment applies also to old reducing conditions, but this state is not obtained in the PA.)

It is not clear why the K_d for radium in cementitious materials differs substantially for reducing and oxidizing conditions. The PA assigns a much higher radium K_d for middle oxidizing conditions (100 mL/g) and old oxidizing conditions (70 mL/g) than for middle reducing conditions (3 mL/g). In geochemical systems, radium is not redox sensitive. The large increase in radium K_d, and attendant decrease in radium release rate, as conditions become oxidizing is, therefore, unexpected. In addition, reference information was not provided for the Berry, et al. document cited in the discussion of radium K_d values under oxidizing conditions in the source document WSRC-STI-2007-00640 (Table 10).

Path Forward: Provide the basis for neglecting recent observations of a lack of iodine sorption in recommending a non-zero K_d for iodine for old cementitious materials.

Discuss the geochemical justification for the radium K_d values for cementitious materials, particularly with respect to the large increase as conditions become oxidizing. Provide information on the Berry et al. reference cited in WSRC-STI-2007-00640 Table 10.

SP-15 Comment: The basis for the adopted technetium pseudo-K_d of 1,000 mL/g for reducing conditions is not clear.

Basis: In the shrinking core model for cementitious materials, DOE used a technetium pseudo-K_d of 1000 mL/g for reducing conditions, applied to both middle and old ages. The technical basis for this value is not clear, particularly in light of uncertainties regarding recent data on technetium sorption (SRNS-STI-2008-00045) and the scarcity of other applicable data. Among the data reported in two recent site-specific studies (SRNS-STI-2008-00045 and WSRC-STI-2007-00640), only one set of technetium values—obtained from fresh reducing grout—yielded values on the order of 1,000 mL/g (WSRC-STI-2007-00640 Table 2). Values for aged reducing grout were much lower.

Additional measurements have recently been performed for the sorption of Tc and other radionuclides to saltstone formulations (SRNL-STI-2009-00636). In this report, the sorption of Tc was measured on saltstone formulations containing 45 dry wt-% (i.e., the formulation for saltstone assumed in the PA) and 90 dry wt-% reducing slag. The K_d values reported in Figure 6.16 for sample TR547 (45 dry wt-% slag) were less than 100 mL/g for both 1 and 4 days; thus, this data also does not seem to support a technetium pseudo-K_d of 1000 mL/g for reducing conditions. Note the text of the executive summary of SRNL-STI-2009-00636 states "Saltstone formulations under reducing conditions had K_d values between 32 (0 dry wt-% slag) and 4,370 mL/g (45 dry wt-% slag)". However, the data presented in Figure 6.16 and Tables 10.22 and 10.30 of SRNL-STI-2009-00636 implies that these K_d values correspond to 45 and 90 dry wt-% slag instead of 0 and 45 dry wt-%.

Section 4.2.3.2.4 of the PA indicates that the pseudo-K_d for Tc used in the shrinking-core model is pessimistic compared to the value of 5000 mL/g recommended in Table 11 of the PA. The recommendation in Table 11 appears to be based (1) data from experiments described in SRNS-STI-2007-00640 and (2) text in Bradbury and Sarott (1995) (although not the value of 1000 mL/g actually recommended by Bradbury and Sarott [1995]). As previously discussed, the experiments in WSRC-STI-2007-00640 were based on fresh grout, which is expected to have significantly different properties from aged grout. The text of Bradbury and Sarott (1995) indicates that distribution ratios of ~5,000 ml/g have been reported using Tc (IV) at trace levels (<10^{-11} M) and the reducing agent sodium dithionite. However, these results do not appear to be applicable to saltstone because saltstone does not contain a strong reducing agent such as sodium dithionite. Site-specific values based on measurements of Tc sorption to simulated saltstone, such as the measurements recently reported in SRNL-STI-2009-00636 are expected to be more relevant.

Path Forward: Provide further support for the adopted technetium pseudo-K_d of 1,000 mL/g for reducing conditions in light of the data reported in SRNL-STI-2009-00636 and the uncertainties in K_d values for Tc discussed in the basis. Clarify whether the K_d values reported in the executive summary of SRNL-STI-2009-00636 apply to saltstone formulations containing 0 and 45 dry wt-% slag or formulations containing 45 and 90 dry wt-% slag.

SP-16 **Comment:** The basis for the range of reduction capacities over which the shrinking-core model transitions to oxidizing K_d values for technetium is not clear.

Basis: PA Figure 4.2-41 shows how the shrinking core model varies the technetium K_d for cementitious materials based on the calculated reduction capacity for a cell. Neither the PA nor the cited supporting report (SRNL-STI-2009-00115) explains how the modelers chose the reduction capacity value of 0.005 meq e-/mL at which the K_d begins to change from reducing to oxidizing. This transition is critical to the model's prediction of when technetium becomes mobile and influences groundwater-based dose.

Path Forward: Provide the technical basis for the reduction capacity range over which the shrinking core model varies the technetium K_d for cementitious materials.

SP-17 **Comment:** Neglecting gas-phase diffusion of oxygen appears to be inconsistent with the PORFLOW result that saltstone fractures are not completely saturated.

Basis: The PA indicates that gas-phase diffusion of oxygen is neglected because saltstone is assumed to be nearly 100 percent saturated. However, the PORFLOW model indicates in some cases, fractures may experience much lower saturations. For example, the PORFLOW model indicates that, at maximum infiltration, fractures in Case C are 40 to 50 percent saturated. At lower infiltration rates, the cracks are expected to be less saturated. It appears saltstone oxidation may be underestimated in cases representing fractured saltstone (e.g., Sensitivity cases B, C, D, E, and the synergistic case).

Furthermore, as described in "*Numerical Flow and Transport Simulations Supporting the Saltstone Disposal Facility Performance Assessment*" (SRNL-STI-2009-00115) the elevated hydraulic conductivity of Case E is intended to represent "an extensive network of smaller-scale cracks". Thus, an additional concern is that, because of the relatively larger number of (small-scale) cracks in Case E as compared to the other cases, the effect of neglecting gas-phase diffusion may be more pronounced in this case.

Path Forward: Provide additional basis for neglecting gas-phase oxygen diffusion in cases representing fractured and degraded saltstone or provide updated dose estimates for cases representing fractured and degraded saltstone considering the potential effects of gas-phase oxygen diffusion.

SP-18 **Comment**: Additional justification is required for the uncertainty ranges used for K_d values in cementitious materials.

Basis: SRNL-STI-2009-00150 uses site-specific sediment sorption data from WSRC-STI-2008-00285 (specifically, for sandy soils) as the basis for the 95 percent confidence levels applied to K_ds for cementitious materials that are used in the PA GoldSim stochastic analyses. This approach results in a range of uncertainty for K_d values of only a factor of seven (PA Table 5.6-5). No basis was presented for applying these limits, which were based on analysis of natural system media, to the cementitious materials distributions. If the true uncertainties or variabilities in cementitious material K_d values were underestimated, the PA may not have adequately represented the uncertainty of dose evaluations.

Path Forward: Provide the rationale for using the sandy-soil-based uncertainty distribution for cementitious materials K_d values and the basis for concluding that this approach does not underestimate uncertainty in radionuclide sorption to cementitious materials.

Vault Performance

VP-1 **Comment:** Additional analysis is needed to assess the applicability of the degradation mechanisms responsible for the observed fracturing of Vault 1 and 4 walls and the degradation mechanisms described in SRS-REG-2007-00041 to the FDCs and to other parts of Vaults 1 and 4.

Basis: The PA and supporting documents predict the FDC walls, floors, and roofs as well as the floors of Vaults 1 and 4 to remain essentially intact with hydraulic conductivities increasing by less than an order of magnitude by the end of a 10,000 year compliance period. This prediction is based on the conclusions of "*Numerical Flow and Transport Simulations Supporting the Saltstone Disposal Facility Performance Assessment*" (SRNL-STI-2009-00115). The walls of Vaults 1 and 4 have already shown cracking and were modeled in the PA with an increased saturated hydraulic conductivity and a relative permeability curve for fractured concrete.

As discussed in report "*Z-Area Industrial Solid Waste Landfill Vault Cracking",* the reinforced concrete construction of Vaults 1 and 4 was designed for gravity loads plus the hydrostatic pressure associated with saltstone grout (ESH-WPG-2006-00132). According to the report "*Savannah River Site Saltstone Disposal Facility Vaults 1 and 4 Overview"*, cracking developed in Vault 1 that may have stemmed from construction and operational events that date back to 1988 (LWO-CES-2006-00010).

The cause of observed fracturing in the walls of Vaults 1 and 4 was determined to be (i) the hydrostatic pressure exerted by 25 ft of hydrostatic head in the gap between the cured saltstone and the vault wall, (ii) thermal shock, and/or (iii) drying shrinkage from non-ideal concrete mixing and inadequate curing practices (SRNL-STI-2009-00115). Sheet drains were installed to remove any free liquid near the inside of the wall as a defense in depth, as the FDCs are designed to handle hydrostatic fluid pressure. However, as discussed in ESH-WPG-2006-00132, Vaults 1 and 4 were also designed to handle hydrostatic pressures (although it is not clear if Vault 1 was damaged during construction and operation).

In addition to the vault wall degradation that has been observed, additional long-term failure mechanisms may exist within the 10,000 year compliance period. Report SRS-REG-2007-00041 discussed sensitivity cases that were conducted to account for the following potential degradation mechanisms:

- Cracking from seismic events and settlement
- Cracking due to external static loading (weight of overburden and cap)

- Chemical reactions involving the waste components in saltstone which could result in expansion and cracking
- Chemical reactions involving ions in the soil which could result in expansion and cracking
- Chemical reactions involving corrodents in the soil which could cause leaching and an increase in porosity and/or cracking in the vault
- Physical process such as freeze-thaw cycles

Path Forward: If construction and operational events were responsible for the cracking of Vault 1 walls, discuss the current and future construction and operational activities that will prevent this type of cracking in the FDC roofs, floors, and walls as well as the floors of Vaults 1 and 4.

Provide engineering calculations to demonstrate whether the hydrostatic head of the water in the annulus between the saltstone and the vault walls was responsible for the cracking of vault 4 walls (e.g., by comparing the hydrostatic head to expected wall strength and the pressure from grout lifts). Provide engineering calculations for the hydrostatic pressure resulting from the grouting of FDCs and compare this pressure to the expected FDC wall strength.

If the failure mechanisms for the Vault 1 and 4 walls are thermal gradients or drying shrinkage, which can be expected for all cementitious material, provide a basis for assuming FDCs and the floors of Vaults 1 and 4 have not degraded similarly to the Vault 1 and 4 walls.

Provide the basis for excluding the degradation mechanisms discussed in SRS-REG-2007-00041 from the analysis of the predicted performance of the FDCs over the 10,000 year period of performance.
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VP-2 **Comment:** Additional basis is required for neglecting disposal unit degradation mechanisms other than sulfate attack.

Basis: Section 4.2.3.2.4 of the PA indicates that degradation of disposal unit concrete is believed to be dominated by external sulfate attack. However, the basis for neglecting other forms of degradation of the Vault 1 and 4 roof and floor, as well as the FDC roof, walls, and floors is not discussed, although other forms of degradation are possible.

For example, one of the key references supporting the calculation of sulfate attack "*Evaluation of Sulfate Attack on Saltstone Vault Concrete and Saltstone*" (SRNS-STI-2008-00050) recommends that, given the high alkalinity of the solutions used in the model, the risk of alkali silica reaction should be considered in a more global performance assessment study.

As another example, the design of Disposal Unit 2 includes significant amounts of carbon steel components (e.g., rebars, prestressing wires, diaphragms). These components could corrode, leading to expansive reactions that could cause cracks to

form in the concrete. In addition, the roofs of Vault 4 and the FDCs have a significant number of steel penetrations. It does not appear that corrosion cracking around these penetrations was considered as a degradation mechanism of the Vault 4 or FDC roofs. Furthermore, because carbonate was not included in the sulfate attack model, decreasing pH due to carbonation also was excluded from the model. In particular, groundwater was assumed to be pure water at pH 7. Thus, any pH output resulting from the STADIUM sulfate attack simulations could not be relied upon to indicate whether carbon steel depassivation would occur.

Early hydraulic degradation of disposal unit roofs, floors, and walls is addressed non-mechanistically in the synergistic case discussed in PA Section 5.6.6.5. The results of this modeling case (Table 5.6-20) indicate that, even if the Vault 1 and 4 floors and roof, and the FDC floors, roofs, and walls are assumed to be hydraulically degraded to have soil properties at 500 years, the performance objective for an off-site member of the public would still be met. However, as discussed in SP-3 and SP-4, it is unclear whether the synergistic case is based on unrealistically optimistic hydraulic characteristic curves for saltstone, and, therefore, its degree of overall conservatism is unclear. It also is unclear whether a potential update to the synergistic case would also show that the performance objectives are met. Furthermore, because the base-case result is an important factor in the compliance determination, it is important to be able to understand the potential for increased hydraulic degradation of the disposal unit floors, walls, and roofs in the base case.

Path Forward: Provide justification for neglecting other forms of degradation of disposal unit cementitious materials, including alkali silica reaction, corrosion cracking, and other relevant forms of degradation. The justification should address Vault 1 and 4 floors and roofs as well as FDC walls, roofs, and floors. Alternately, the base-case model could be updated to reflect the potential effects of applicable degradation mechanisms.

If maintenance of an alkaline pH near steel components of the disposal units is relied upon to demonstrate steel passivity, the model generating predicted pH values should account for local effects near steel components (e.g., pH depression by carbonation in fractures near steel components) or address why such phenomena can be neglected.

A summary of observed reinforcement corrosion of concrete at SRS should be provided. Provide information to demonstrate that modeling of engineered systems in this application is consistent with observed performance of analogous systems at SRS.

If the justification for neglecting other forms of degradation is based on the results of the synergistic case, the response should be consistent with the response to other comments in this document.

VP-3 **Comment:** The effect of modeling disposal unit floors as completely reducing for the entire performance period, and beyond 20,000 years, should be analyzed.

Basis: Although a shrinking-core model was used to model the release of Tc-99 from saltstone, the vault walls and floor were presumed to be completely reducing until completely oxidized. This assumption seems unrealistic, as the vault walls and floors would be expected to oxidize near exposed surfaces and fractures just as the saltstone does. This assumption appears to be conservative with respect to the vault walls, because a more gradual release would produce a lower peak than a sudden release when the wall is presumed to fully oxidize. However, this assumption appears non-conservative in the case of the floor, which is modeled as remaining reducing beyond 30,000 years (Table 4.2-17). Thus Tc-99 release may be underestimated, because once released from the saltstone it is modeled as being strongly held in the unoxidized floor during the entire performance period, whereas chemical oxidation is expected to occur around the edges of the floor and near fractures.

Although complete oxidation of Vault 1 and 4 floors was addressed non-mechanistically in the oxidized concrete sensitivity case discussed in Section 5.6.6.6, this case does not address oxidation of the FDC floors or walls.

Path Forward: Address the effect of limiting release of Tc from the disposal unit floors by presuming the floors remain 100% reducing instead of becoming partially oxidized, as would be predicted by a shrinking-core model.

VP-4 **Comment:** The effects of the potential inventory in Vault 1 and 4 floors on radionuclide release should be analyzed.

Basis: The PA indicates that salt waste is assumed to fill the pore spaces in Vault 1 and 4 walls. However, no similar inventory is considered in Vault 1 and 4 floors. It is not clear why inventory could fill the pore spaces of the walls but not the pore spaces in the walls.

Path Forward: Justify why the Vault 1 and 4 floors are not assumed to contain inventory in the pore spaces, or estimate the effect on dose to an off-site member of the public of assuming the Vault 1 and 4 floors contain salt waste in the pore spaces.

Far-field transport

FFT-1 **Comment:** Additional justification is required for the uncertainty ranges used for K_d values in site soils.

Basis: The basis for the distribution coefficient variability used in the GoldSim model (Table 5.6-5) is not clear. In general, distribution coefficient uncertainty distributions are expected to be element-specific because of the varying quality of information available for each element. For example, distribution coefficients based on several site-specific samples are expected to be less uncertain than literature values. Table 5.6-5 indicates that the ranges are based on the report "*Distribution Coefficients (K_ds), K_d Distributions, and Cellulose Degradation Product Correction Factors for the Composite Analysis*" (SRNL-STI-2009-00150). However, this report (SRNL-STI-2009-00150) does not provide a discussion of the basis for uncertainty ranges, and instead references

"*Distribution of Sorption Coefficients (K_d Values) in the SRS Subsurface Environment*" (WSRC-STI-2008-00285).

Path Forward: Provide a basis for the uncertainty distributions provided in Table 5.6-5 of the PA. If WSRC-STI-2008-00285 provides a discussion of the bases for the distributions used in Table 5.6-5 of the PA, provide this reference.

FFT-2 **Comment:** It is unclear whether any site-specific K_d value measurements have been performed for the sorption of radium to soil.

Basis: The results of the performance assessment indicate that radium is a key radionuclide. In addition, Table 5.6-14 indicates that the peak dose to a member of the public within 10,000 years in the base case is sensitive to the K_d for radium in sandy soil. According to Table 4.2-15 in the PA ("Recommended K_d Values for Backfill and the Vadose Zone"), a K_d value of 17 mL/g was selected for the backfill and a K_d value of 5 mL/g was used for the vadose zone. These K_d values were based on information provided in Kaplan (WSRC-TR-2006-00004). Table 10 of Kaplan 2006 implies that the K_d values for radium were based on measured K_d values for strontium.

Path Forward: Clarify if radium K_d values have been measured for soil at SRS. If these measurements have been performed, provide information on the results of these measurements.

FFT-3 **Comment:** Additional justification is needed for the K_d of selenium in vadose and backfill soils.

Basis: The PA references the report "*Geochemical Data Package for Performance Assessment Calculations Related to the Savannah River Site*" (WSRC-TR-2006-00004) as the basis for a K_d of 1000 mL/g for Se in backfill and vadose zone soil (Table 4.2-15 in the PA). In general, literature values are two to three orders of magnitude lower than the values cited in WSRC-TR-2006-00004 (e.g., Fuhrmann and Schwartzman, 2008; PNNL-13895). Site-specific values are, in general, far preferable to literature values. However, it is important to understand the basis for large deviations from expected values (e.g., particular properties of the site-specific soil or water chemistry).

Furthermore, in the reference used in the PA (WSRC-TR-2006-00004), the authors note the K_d for sandy soils exhibits a "characteristic decrease in K_d values as the pH increased" in the range from pH 3.9 to pH 6.7, with no additional data available above pH 6.7. In the reference the K_d in sandy soil was 1311 ± 384 mL/g at pH 5.3 and 601 ± 65 mL/g at pH 6.7 (WSRC-TR-2006-00004). The basis for choosing a K_d representative of low-pH soil as compared to a more neutral soil is unclear, especially in light of the potential for alkaline buffering of the vadose zone soils by the significant quantity of cementitious materials in the SDF.

Path Forward: Provide a basis for choosing a K_d value representative of low pH soils as compared to more neutral soils. In determining an appropriate pH for modeled soils, consideration should be given to the potential impact of the cementitious materials in the SDF on the pH of water in the vadose and backfill soils.

Air Pathway

AP-1 **Comment:** The dose from the radon pathway was not included in the dose assessment of the air pathway (Section 4.5 of the PA).

Basis: The flux rates expected from the radon generated by the decay of radium in saltstone were calculated and presented in Section 4.5 of the PA. However, the dose associated with these flux rates of radon for an off-site member of the public or an inadvertent intruder inhabiting the site was not included. As discussed in comment II-1, an inadvertent intruder is assumed to inhabit the site after the end of institutional controls, and may live directly above a disposal unit.

Path Forward: Provide a calculation of the expected dose from the radon pathway to an off-site member of the public and to an intruder residing on site.

AP-2 **Comment:** The calculations used for the air pathway dose may not have adequately evaluated the dose from this pathway. The materials were assumed to remain constant over the simulation period and degradation of the wasteform and vault does not seem to have been considered. Also, the sensitivity of the calculated land surface flux rates of radionuclides to the assumed moisture content in the cover was also not evaluated.

Basis: As described in Section 4.5 of the PA, the gaseous flux of radionuclides diffusing from the wasteform and through the cover was calculated using PORFLOW. The materials were assumed to remain constant over the simulation period and degradation and cracking of the wasteform and vault does not seem to have been considered. The flux of gaseous radionuclides out of the saltstone and through the vault may be higher if degradation and fracturing of the saltstone and vault ceiling occurs.

The materials in the cover were assumed to be partially saturated at saturation fractions presented in Tables 4.5-4, 4.5-5, and 4.5-6. The assumed saturation fractions for some portions of the cover were high, and it is not clear if these levels of saturation will be maintained at all times throughout the entire performance period.

The rate of diffusion through partially saturated porous media is very dependent on the amount of saturation. The gaseous flux of radionuclides through the cover, and the resulting dose, could therefore vary greatly depending on the moisture content of the cover. The radon flux is particularly dependent on the moisture content of the cover because of its short half life. Even though the gaseous fluxes calculated were small, it is not clear if the fluxes would remain this small if the cover has a lower amount of saturation than was assumed in the calculations.

In addition, the basis for the emanation coefficient selected for radon is not clear. As

noted in the text of the PA, the emanation factor is dependent on the moisture content and is usually higher with higher moisture contents. Section 4.5.2.5 of the PA indicates that the chosen value is appropriate for a soil with a low moisture content. Thus, the emanation factor selected seems to be inconsistent with the high level of saturation assumed for the saltstone wasteform.

Section 4.5.2.1 of the PA indicates that the primary uncertainty in the estimation of the apparent Henry's Law constants is the use of lower ionic strengths in the calculations (0.015 molal) than those estimated for saltstone pore fluids (~6 molal). Higher ionic strengths can cause more partitioning into the gaseous phase (i.e., salting out). The PA states that it is unlikely that the activity coefficients would increase by more than a factor of 10 due to this effect, but the basis for this statement is not clear. The reference for this statement is a textbook, and the specific basis for this statement in the textbook is not clear. Thus it is not clear it whether the assumptions on which this conclusion is based are applicable to saltstone.

Path Forward: Evaluate if the calculated air pathway doses are sensitive to the assumption that the material properties remain constant and that degradation of the saltstone and vaults does not occur. Provide an evaluation of the sensitivity of the calculated gaseous flux rates, including the radon flux, to the assumed amount of saturation of the layers of the cap. Provide an evaluation of the sensitivity of the radon flux to the radon emanation factor. Provide more support for the statement that it is unlikely that the activity coefficients would be unlikely to increase by more than a factor of 10 due to salting out.

<u>Inadvertent Intrusion</u>

II-1 **Comment:** Key assumptions about the potential pathways of exposure of an inadvertent intruder appear to underestimate dose.

Basis: The assumed location of the inadvertent intruder was 1 m from the perimeter boundary of the Saltstone Disposal Facility. The dose to the intruder at this location includes the dose at 1 m from the FDCs nearest to the perimeter boundary as well as the dose from the radionuclides from the upgradient vaults that transport to this location within 10,000 years. This assumed location appears to be optimistic because the dose at a location 1 m from vault 4 would likely be higher than the dose at 1 m from a FDC because the size of vault 4 is larger and because the FDCs have many more engineered features then vault 4. The inventory in the individual FDCs is also expected to vary from vault to vault. The dose to an intruder at 1 m from a vault that had a higher inventory would be higher than the dose to an intruder located 1 m from a FDC with the average inventory. As defined in 10 CFR 61.2, an inadvertent intruder may occupy the disposal site and is not assumed to be confined to the buffer zone of the site.

In addition, it is not clear if the 1 m dose corresponds to the dose at the 1 m perimeter or if it corresponds to the dose from soil and water with the average concentration in the grid cell located at approximately 1 m. Because a 50 ft by 50 ft mesh was used to define the grid cells in the saturated zone, the average concentration of radionuclides in the

water and soil in these grid cells could be much less than the concentration at 1 m, particularly for those radionuclides that sorb strongly to soil and are not expected to travel quickly in the saturated zone. Although it may be appropriate to average water concentrations over the grid cell, depending on well capture area, it is less clear if it is appropriate to average soil concentrations over a 50 ft by 50 ft grid.

The dose from the air pathway was not included in the assessment of the dose to an inadvertent intruder. The calculated inhalation dose from radionuclides that diffused from the saltstone wasteform to the atmosphere air was small, but this calculated dose is expected to be greater for an intruder residing directly above a disposal unit. In addition, this calculated dose may be very sensitive to the assumed moisture content in the cap. If the response to AP-2 indicates that the air pathway dose, including the dose from radon, could be non-negligible for an intruder residing directly above a disposal unit, the air pathway dose should be included in the assessment of dose to an inadvertent intruder. In addition, as described in B-2, the poultry and egg pathways were not included in the dose assessment. If the response to B-2 indicates that these pathways should be included for the member of the public, then these pathways should be included for the chronic intruder as well.

Path Forward: Provide justification for the selected location for the intruder or provide an intruder analysis that considers the dose to an intruder at a location 1 m from Vault 4 and from a FDC that has the maximum expected inventory. Clarify if the 1 m dose is at a distance of exactly 1 m or if this dose corresponds to the average dose over a 50 ft by 50 ft grid cell located at the 1 m perimeter. If appropriate, the intruder dose assessment should be revised to include the dose from the air pathway, including radon, and from animal pathways other than the beef and milk pathway (e.g., poultry and egg pathways).

II-2 **Comment:** The basis for the use of Case A to calculate the intruder dose is not provided. Additionally, the methodology used for determining the key radionuclides for the intruder uncertainty/sensitivity analysis may have resulted in radionuclides that are risk significant to the intruder being excluded from this analysis. As a consequence, the results of the uncertainty/sensitivity analysis may not capture the true uncertainty in the intruder dose.

Basis: In the deterministic calculation of the dose to the chronic intruder, the 1 m groundwater concentrations were calculated using the Case A modeling case in PORFLOW. Because this case does not include degradation or cracking of the saltstone, the dose calculated from this case may not adequately capture the expected intruder dose. A probabilistic uncertainty/sensitivity analysis was performed for the chronic intruder using GoldSim, and as part of this assessment, the effect of the case selection on the dose was evaluated. However, this uncertainty/sensitivity assessment was based on the key radionuclides identified as causing the greatest dose at 100 m. This approach may have excluded radionuclides that have high soil K_d values because they do not travel quickly enough to reach a distance of 100 m within the evaluation period. However, some of these radionuclides could reach a distance of 1 m within 10000 yrs and could cause a significant dose to the intruder. Also, as discussed in PA-3, the use of Case A to determine the list of key radionuclides may have led to the omission of some potentially dose-significant radionuclides.

In addition, some of the comments in this document related to the calculation of the dose to the member of the public also could apply to the intruder calculation. The chronic intruder calculation should be updated to address these comments if appropriate.

Path Forward: Provide justification for the use of Case A in the calculation of the deterministic chronic intruder dose or provide the results of an assessment of the dose to an inadvertent intruder in cases representing degraded saltstone, cap, and vault conditions. Evaluate if any radionuclides that could potentially cause a significant dose to the intruder were excluded from the uncertainty/sensitivity analysis, and if so, provide a revised uncertainty/sensitivity analysis. Evaluate whether the responses to comments on the dose assessment to the member of the public affect the intruder analysis and provide a revised analysis if applicable.

Biosphere

B-1 **Comment:** The basis for excluding biotic transfer factors from the uncertainty analysis is unclear.

Basis: Section 5.6.3.7 indicates that only the most likely values of the transfer factors provided in Tables 4.6-1 though 4.6-4 (i.e., soil-to-vegetable, feed-to-milk, feed-to-meat, and water-to-fish transfer factors) were used in the analysis, although a range of values is presented for each transfer factor for each element in Tables 4.6-1 though 4.6-4. The basis for excluding these transfer factors from the probabilistic analysis is unclear, given that fish and vegetable consumption were two of the three significant pathways identified as contributing to the dose to a member of the public at 10,000 years in the base case in Section 5.5.1.4 of the PA. An understanding of the factors to which dose is most sensitive is important to establishing factors to monitor.

Path Forward: Provide a basis for excluding the biotic transfer factors listed in the basis from the uncertainty analysis, or provide an updated uncertainty analysis that includes the uncertainty in the transfer factors.

B-2 **Comment:** The animal product pathways included in the dose assessment are the beef, milk, and finfish pathways. A basis for excluding the other animal product pathways (e.g., consumption of poultry and eggs) from the dose assessment is not provided.

Basis: According to Table 4.6-7 in the PA, the animal products assumed to be consumed include meat, milk, and finfish. The meat pathway seems to only include the ingestion of beef. For example, based on the reference cited in Table 4.6-7 as the basis for the amount of meat consumed (WSRC-STI-2007-00004), the amount of meat consumed seems to correspond to the amount of beef eaten, not the total amount of meat. The basis for the exclusion of the consumption of other animal products, such as poultry and eggs, is not clear. Animals other than cows might be raised on site, and these animals would likely consume groundwater from the site and may consume feed grown on site.

According to Tables 2.6 and 2.7 in PNNL-13421 the transfer factors for poultry are greater than those for beef, so the dose from the consumption of poultry could be higher than the dose from the consumption of beef. In addition, radionuclides can also concentrate in eggs. This can be particularly true for lead. Because the results of the performance assessment indicate that one of the key radionuclides is Ra-226, a parent radionuclide of Pb-210, the Pb-210 dose from the consumption of eggs produced on-site may not be negligible.

Path Forward: Provide the basis for the exclusion of animal pathways other than the beef, milk, and finfish pathways or provide an analysis of the dose from other animal pathways (e.g., poultry, egg).

B-3 **Comment:** The effects of radionuclide build-up in irrigated soils may be underestimated.

Basis: Descriptions of the biotic pathways in 5.4.1 appear to present conflicting information about the consideration of radionuclide build-up in irrigated soil. For example, Section 5.4.1.2 describes the calculation of the dose from direct exposure to irrigated soil, but does not specify how soil concentrations are calculated. The equation for the dose from the ingestion of vegetables in Section 5.4.1.1 appears to use groundwater concentrations, and does not appear to account for build-up of radionuclides in irrigated soils after multiple years of irrigation. Because vegetable uptake is a significant pathway (see PA Table 5.5-9), neglecting radionuclide build-up in soil could affect the final dose results.

Furthermore, Section 5.6.3.7.4 indicates that for both the intruder and off-site member of the public, irrigation and harvesting of vegetables is assumed to occur during the first year of residence, and only uses a 183 day radionuclide build-up time. No explanation is provided of why irrigation and harvesting of vegetables is not assumed to occur in subsequent years, when radionuclide concentrations in soil could have increased due to build-up.

Path Forward: Explain how radionuclide build-up in soils was considered in the biotic pathways described in Section 5.4 of the PA. If radionuclide build-up is neglected, justify why it is neglected or provide an estimate of the effects on the dose results. Provide an explanation for why a 183 day build-up time is used, as described in Section 5.6.3.7.4, and why irrigation and harvesting of vegetables is assumed to occur for only one year. Alternately, provide an estimate of the effect on dose of considering radionuclide build-up during multiple years of irrigation.

<u>ALARA analysis</u>

A-1 **Comment:** Social, economic, and public policy considerations do not appear to have been considered in an analysis of maintaining doses “As Low as is Reasonably Achievable” (ALARA).

Basis: The performance objectives of 10 CFR Part 61, Subpart C, require that doses to the off-site member of the public and to workers be maintained ALARA. As discussed in Section 5.7 of the PA, the goal of the ALARA process is to attain the lowest practical dose given social, technical, economic, and public policy considerations. The discussion in Section 5.7 provides several examples of technical issues that were considered in the ALARA analysis, but does not include a discussion of social, economic, or public policy considerations. Typically, an ALARA analysis presents dose savings and the economic costs of those dose savings, as well as any other costs, such as potential increases in the dose to site workers.

Path Forward: Provide a discussion of any social, economic, and public policy issues that were considered in concluding that doses have been maintained ALARA.

Clarifying Questions

1. Section 3.2.1.1.2 discusses a 3-inch gap between disposal units in Vault 1. Clarify whether the area referred to as a gap is an open area that could fill with rainwater or if it represents a wall or barrier between disposal units.

2. Section 4.2.1.1 indicates that daughters other than daughters of Cf-249, Pu-244, Pu-242, and Cm-243 were “removed from modeling consideration and were not assigned an initial SDF inventory”. Clarify if the radionuclides removed from consideration were limited to daughters whose initial inventory was determined not to be significant, or if any daughters were removed whose initial inventory was unknown.

3. Clarify points 3 and 4 in Section 4.2.3.2.4 of the PA. Vault 4 walls seem to be assigned two different conflicting sets of material properties (high quality concrete and fractured concrete). Similarly, in the “hydraulic conductivity” column of Table 4.2-16, Vault 4 walls appear in two rows with two different hydraulic conductivities assigned. Clarify under what circumstances, if any, each hydraulic conductivity was used.

4. Clarify the basis for the selenium K_d of 150 mL/g for old oxidizing conditions. It is not clear from the PA, or the supporting report WSRC-STI-2007-00640, how the value was selected. Clarify whether the evaluation considered the presence in solution of the selenium as selenate, which is potentially less sorptive than selenite.

5. The near field velocity profiles should be included in Section 4.4.4.1.2 as the flow in the saltstone is difficult to ascertain from the velocity vectors provided with the saturation profiles.

6. The “Diffusion Model Implementation” subsection of Section 4.4.4.2.2 indicates the solution to the diffusion model was valid only for radionuclides existing at time equal to zero, and notes “the model does not explicitly recognize in-growth”. The subsection also indicates “However in-growth was implicit to the model via the species concentrations used as arguments in the model.” The meaning of these statements in not clear, because GoldSim cell networks do account for in-growth.

7. Section 5.5.1.2 indicates the significant spike of I-129 in Sector I at 15,080 years is due to the FDC wall hydraulic conductivity increasing by four orders of magnitude at year 15,080. This result seems to imply that the I-129 peak is seen in the 100 m well the same year the I-129 is released from the FDC walls, and does not appear to allow for transit time. If this result is an artifact of time-stepping, it seems the I-129 should arrive at the 100 m well in the next time step, not in the same time step in which the FDC walls are degraded. Please clarify the statement in Section 5.5.1.2.

8. For benchmarking cases B-E (Sections 5.6.2.3.5 though 5.6.2.3.8), the PA compares the doses predicted based on the PORFLOW model and post-benchmarking GoldSim model resulting from “all modeled radionuclides”. Clarify whether the term “all modeled radionuclides” in this context refers to the original list of radionuclides included in the PORFLOW model or a smaller list of radionuclides modeled during the benchmarking effort.

9. Section 5.6.6.3 indicates the peak dose in Sector B within 10,000 years is 2.1% greater in the sensitivity case representing 10 X faster sulfate diffusion behind the ettringite front than it is in the base case. However, the data in Table 5.6-19 indicate the dose increases from 1.4 mrem/yr to 1.7 mrem/yr (or approximately 21%). Clarify which is the correct information.

10. As described in Section 5.6.6.3, to test the effects of the assumption that the progress of the ettringite front is unaffected by physical degradation of concrete behind the front, a sensitivity case was run for a case in which the diffusion coefficient is increased by a factor of 10. However, it is not clear whether this diffusion coefficient is applied in the entire block of cementitious material, or if it is applied only behind the ettringite front. The diffusion coefficient value used in this sensitivity case is based on an empirical relationship between the diffusion coefficient and hydraulic conductivity (Equation (1) in Section 5.6.6.3) (Figure 5.6-76), but no reference is supplied for the data. In addition, Section 5.6.6.3 indicates that soil suction levels under nominal saltstone closure cap degradation conditions vary through space and time across a typical range of approximately 0.10 to 0.01 cm, and that the conductivity of cracked concrete ranges up to three orders of magnitude higher than the conductivity for uncracked concrete in this range. However, Figure 5.6-77 does not show this range of suction heads. Clarify whether the modified diffusion coefficient is applied only behind the ettringite front or in the entire block of cementitous material. Supply a reference for the data used in Figure 5.6-76. Clarify whether the reported range of relevant suction heads in Section 5.6.6.3 is correct and, if necessary, modify Figure 5.6-77 to show the applicable range of suction heads.

11. Section 5.6.6.5 of the PA states that the saltstone is assumed to be cracked at the time of closure in the synergistic case. However, the extent and location of the fractures is not specified. Please provide the number of fractures, the assumed location of the fractures, and the assumed fracture area.

12. Section 7.1.1.4 indicates that peaks at 15,000 and 16,000 years are due to hydraulic and chemical failures of the FDC walls, respectively. The dose results from the synergistic case (Figure 5.6-83) show the characteristic peak between15,000 and 16,000 years even though the FDC walls are assumed to fail chemically and hydraulically at 500 years. Clarify the origin of the dose peak between 15,000 and 16,000 years in the synergistic case.

13. Section 7.2.2 lists the assumption that there is not HDPE-GCL layer over Vault 1 and 4 as a conservative assumption. Section 4.2.3.2.2 indicates the HDPE-GCL layer that will be placed above each FDC will not be placed above Vaults 1 and 4. Clarify whether this is a conservative assumption or if the HDPE-GCL layers will not be placed above Vaults 1 and 4.

14. Section 8.2 indicates that the probabilistic sensitivity analyses demonstrated that the groundwater doses are most sensitive to the specific radionuclide inventories. Tables 5.6-14 and 5.6-15, however, appear to indicate that the dose in Case A and Case C are most sensitive to parameters related to radionuclide release and transport, and parameters related to vegetable production and consumption. Clarify the conclusion presented in Section 8.2 or the results presented in Tables 5.6-14 and 5.6-15 as appropriate.

15. Clarify the technical basis for the plutonium Kd of 1000 mL/g for old oxidizing cementitious materials. The source cited in PA Table 4.2-18 (SRNL-TR-2009-00019) refers to one document (SRNS-STI-2008-00045, Tables 4 and 5) that does not appear to give this value and to another (WSRC-STI-2007-00640, Table 4) that does not appear to include the cited table.

16. Clarify the difference between the entries “Ancestors not present” and “no decay source” in the column “reason for elimination from initial inventory” of Table 4.2-6.

17. Provide the saturation of the vault and FDC walls in Tables 4.5-4 through 4.5-6 to allow independent verification of unsaturated hydraulic conductivities.

18. Tables 5.6-12 and 5.6-13 report doses from the GoldSim model for Cases A and C. Clarify which sectors correspond to the reported maximum dose to a member of the public at any sector within 20,000 years.

19. Table 5.6-18 indicates that in the base case, the Vault 4 wall is assumed to be hydraulically failed after 100,000 years. In other locations, the PA indicates that the Vault 4 wall is assumed to be hydraulically failed at time equal to zero. Table 5.6-18 also indicates that in the 10X sulfate attack case, the Vault 4 wall is assumed to be hydraulically degraded at 16,000 years. Clarify whether the Vault 4 wall is assumed to fail hydraulically at 16,000 years in the 10X sulfate case, or whether it is assumed to be failed at time equal to zero. Clarify whether this timing is before or after the wall is assumed to degrade hydraulically in the base case.

20. In Table 6.5-2, it is not clear what the difference is between rows 1 and 2 or between rows 3 and 4 of this table. Please clarify the row labels.

21. Comment response 36 in CBU-PIT-2005-00131 states that any fracturing of saltstone lifts will be filled in by the succeeding pour. However, the "Z-Area Industrial Solid Waste Landfill Vault Cracking" (ESH-WPG-2006-00132) states that saltstone will not flow through any cracks in the vault walls because it is too viscous and sets up very quickly. Clarify the conditions under which saltstone is expected to flow into cracks in cementitious materials and whether these conditions explain the different conclusions made with respect to saltstone flowing into saltstone lifts and vault walls.

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