May 26, 2005

Mr. Mark A. Gilbertson
Deputy Assistant Secretary
Environmental Cleanup and Acceleration, EM-20
Office of Environmental Management
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON THE DRAFT SECTION 3116 DETERMINATION FOR SALT WASTE DISPOSAL AT THE SAVANNAH RIVER SITE

Dear Mr. Gilbertson:

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the "Draft Section 3116 Determination, Salt Waste Disposal, Savannah River Site," dated February 28, 2005, and the associated documentation provided. We have attached a request for additional information (RAI), which is a list of comments for which the NRC staff requires responses from the U.S. Department of Energy (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 require DOE response.

In order to meet the current schedule, in which we are endeavoring to complete our review by August 31, 2005, we need to receive your responses to the RAI on or before June 30, 2005. If it would be useful to DOE, we would be happy to meet with your staff to discuss our RAI or your responses. If you have any questions, please contact Anna Bradford, senior project manager in the Division of Waste Management and Environmental Protection, at 301-415-5228.

Sincerely,

/**RA**/

Scott C. Flanders, Director
Environmental and Performance
  Assessment Directorate
Division of Waste Management and
  Environmental Protection
Office of Nuclear Material Safety
  and Safeguards

Attachment: RAI

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| DATE | 5/26/05 | 5/26/05 | 5/26/05 | 5/26/05 | |

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# Request for Additional Information for the Draft Section 3116 Determination for Salt Waste Disposal at the Savannah River Site (SRS)

## Main Review Documents

Cook, J. and J. Fowler. "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility (U)." WSRC–RP–92–1360. Rev. 0. Aiken, South Carolina: Westinghouse Savannah River Company. December 1992.

WSRC. "Addendum to the Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility at the Savannah River Site." WSRC-RP-98-00156, Rev. 0, Aiken, South Carolina: Westinghouse Savannah River Company. April 1998.

Cook, J., D. Kocher, L. McDowell-Boyer, and E. Wilhite. "Special Analysis: Reevaluation of the Inadvertent Intruder, Groundwater, Air, and Radon Analyses for the Saltstone Disposal Facility." WSRC–TR–2002–00456. Rev. 0. Aiken, South Carolina: Westinghouse Savannah River Company. October 2002.

DOE. "Draft Section 3116 Determination Salt Waste Disposal Savannah River Site." DOE–WD–2005–001. Aiken, South Carolina: DOE, Savannah River. February 2005.

## Structure of Comments

The U.S. Nuclear Regulatory Commission (NRC) staff's review comments are separated into major topical areas to facilitate the U.S. Department of Energy's (DOE's) responses. A numbered reference system is used, and all references are cited at the end of this request for additional information. The pertinence of some comments are conditional on the outcome of the resolution of other comments (e.g., the credibility of an agricultural intruder scenario), and therefore the responses may be conditional also. In addition to the main review documents listed above, many additional documents were reviewed in lesser detail (see Reference list). The path forward provided for each comment is a recommended approach to resolution; however, the NRC staff understands that there may be more than one method for adequately addressing the technical issues raised in the comments.

## GENERAL/REGULATORY

1. Comment: Major assumptions are not clearly listed and the basis for many assumptions (or the approach to verify the assumptions) is not provided. Concerns about specific assumptions are described below in additional comments; this comment is focused on DOE's overall approach to assumptions.

   Basis: Many of the assumptions are not sufficiently supported to determine whether they are appropriate (e.g., the gravel drain layer of the cap acts as an erosion barrier for 10,000 years or the saltstone degrades at a rate similar to limestone). Many of the assumptions are about key features or processes that directly determine estimated performance. Independent analysis by NRC staff suggests that if key assumptions are not met then there may not be reasonable assurance that the performance objectives can be met.

Path Forward: In a general section or in each relevant section, provide a list of key assumptions, and the basis for the assumption or the approach to verify the assumption. In general, assumptions should have a documented approach to achieve verification (e.g., the future work to confirm the accuracy of the assumption should be described) or a basis that clearly demonstrates that the assumptions are reasonably conservative in which case verification is not necessary.

2. Comment: A number of calculations, in particular many described in Reference 1, were not presented in sufficient detail to allow independent verification of the results.

Basis: Results cannot be independently verified without:

- details of the grout and concrete degradation calculations (see Comment 40)
- details of the pathway screening analysis for milk and meat consumption
- $K_d$ values used in the groundwater pathway calculations (see Comments 48 and 58 for specific details)
- details of the parametric analysis of concrete degradation carried out to identify the combinations that might lead to significant degradation (pg. 3-73 of [1])
- details of the calculations use to estimate the values of the Horizontal Velocity of the Aquifer and Vertical Velocity of the Unsaturated Zone (UZ) that are described as being “Calibrated vs. $NO_3$ arrival time” (pg. 5-5 of [3])
- values of the vertical thickness of the grid blocks that the contaminants are averaged over (pg. 3-83 of [1])
- values of the soil shielding properties assumed in the inadvertent intruder analyses

Path Forward: Provide the information necessary to allow independent verification of the calculations in the reports. Complete responses to other comments should provide sufficient detail to allow for independent verification.

3. Comment: In general, insufficient support is provided for models used in the analysis. See Comments 28, 41, 43, and 55.

Basis: A fundamental component of completing a performance assessment (PA) is the development of adequate support for the numerical modeling results. It is understood that for a performance assessment model involving long periods of time and potential exposures to humans and the environment, model validation in the traditional sense cannot be achieved. However, adequate model support is essential to have confidence that the conceptual models utilized were reasonably correct.

Previous review comments from the DOE PA peer review group and DOE Headquarters indicated a need for DOE-SRS to address key uncertainties and to verify and validate models. In 1993 [2] it was indicated that SRS was seeking appropriate near-field monitoring technology to validate models and assumptions used in the PA. The response to OPS-DTZ-95-0001 in Reference 2 indicates a variety of activities that would possibly be undertaken to address key uncertainties and to verify and validate models.

Path Forward: Provide a description of the near-field monitoring technology that has been evaluated or employed to validate models and assumptions used in the PA. Provide an update on the activities listed in the response to OPS-DTZ-95-0001 [2] that have been accomplished.

4. Comment: There is contradictory information regarding the dose resulting from releases from the saltstone facility for the groundwater pathway.

Basis: The approach in Reference 4 was to scale previous estimates in Reference 1 of groundwater doses based on the current expected waste composition. The resulting maximum groundwater pathway dose in 10,000 years using this approach was 0.2 mrem/yr [4]. However, the analysis in Reference 5 seems to indicate that the groundwater pathway doses would be 6.8 mrem/yr at 10,000 years, which is significantly greater than the doses provided in the draft section 3116 determination [4].

Path Forward: Explain why the more recent calculations in Reference 5 were not used or referenced in the draft waste determination. Explain the differences between the two calculations and clarify the dose estimated for the groundwater pathway.

5. Comment: It is unclear how public and worker exposures will be maintained As Low As Reasonably Achievable (ALARA) during operations.

Basis: Although it is stated that projected worker exposures will be an order of magnitude below 5 rem per year (pg. 68 of [4]), no reference was given to support this estimate. Worker and public exposures from the saltstone facility were significantly less than 5 rem per year for past operations, however the source material used in past operations had significantly less activity than the waste in the current waste determination. Thus, past worker doses cannot be used to bound future worker doses.

Path Forward: Provide estimates of worker and public exposures for the saltstone processing and disposal facilities using current estimated waste activities. Describe specific actions, controls, or processes that will be used to ensure that these exposures will be maintained ALARA.

6. Comment: The Modular CSSX Unit (MCU) and Salt Waste Processing Facility (SWPF) technologies use organic materials to effect Cs-137 removal. Given the potential for explosion [4] with the use of an organic material in processing Tank 48 waste, it is important to ensure that the impacts associated with the use of organic materials in the MCU and SWPF processes has been adequately considered for the saltstone processing and disposal facilities.

Basis: Tetraphenylborate, an organic material employed for Cs-137 removal in the failed In-Tank Precipitation process, has resulted in an explosion hazard for Tank 48 Waste. The selected caustic side solvent extraction (CSSX) process for MCU and SWPF intend to use novel organic based materials for Cs-137 removal from salt wastes. The safety analysis report for the saltstone processing facility indicates that the explosion scenario resulting from benzene generation from Tank 48 waste was the bounding accident for radiological risk to workers. The safety analysis report does not address the organic material in the waste streams resulting from MCU and SWPF.

Path Forward: Provide justification that the current safety analysis report for saltstone processing adequately bounds the radiological risk to workers from explosion hazards associated with organic materials in the waste, including waste resulting from the MCU and SWPF processes.

7. Comment: Footnote 2 on page 9 of Reference 4 states that “In 1997, following consultation with the NRC...DOE operationally closed Tanks 17 and 20.” The consultation with NRC was not complete until June 30, 2000, when NRC sent its final Technical Evaluation Report to DOE.

Path Forward: Revise the wording so as to correctly describe the timeline of events regarding previous tank closures.

8. Comment: Footnote 30 on page 51 of Reference 4 states that “The NRC has stated: ‘The dose methodology used in 10 CFR 61 Subpart C is different from that used in the newer 10 CFR 20 Subpart E. However, the resulting allowable doses are comparable and NRC expects DOE to use the newer methodology in 10 CFR 20 Subpart E.’” The NRC made this statement in its Decommissioning Criteria for the West Valley Demonstration Project at the West Valley Site, Final Policy Statement (Feb. 1, 2002, 67 FR 5003), not in relation to waste determination activities under the National Defense Authorization Act of Fiscal Year 2005 (NDAA).

Path Forward: Revise the wording so that it does not imply that the NRC made this statement in relation to the NDAA. A more appropriate reference for NRC's guidance on dose methodology for compliance with 10 CFR 61 can be found in NUREG-1573.

9. Comment: The draft 3116 determination [4] should specify that the requirement of meeting the performance objectives of 10 CFR 61, Subpart C, applies

whether or not the waste meets Class C concentrations.

Basis: Several statements are made in Reference 4 that imply that the performance objectives of 10 CFR 61, Subpart C, do not apply to waste that meets Class C concentrations. For example, the first paragraph of page 27 states “This includes waste that falls within one of the classes set out in Section 61.55, as well as waste that will be disposed of so as to meet the performance objectives of Subpart C of Part 61.”

Path Forward: Revise wording throughout Reference 4 to clarify that the waste must meet performance objectives of 10 CFR 61, Subpart C, regardless of its classification, as specified in the NDAA.

## REMOVAL OF HIGHLY RADIOACTIVE RADIONUCLIDES TO THE MAXIMUM EXTENT PRACTICAL

10. Comment: Additional information is needed to support the conclusion that use of interim treatment measures before the completion of the SWPF is consistent with removal of highly radioactive radionuclides to the maximum extent practical.

Basis: The NRC agrees with the conclusion in Reference 4 that the determination of whether highly radioactive radionuclides have been removed to the maximum extent practical can include a wide variety of considerations. However, it is expected that any factors included in the determination will be supported by a technical basis and, when possible, quantitative comparisons.

For example, although it is stated that risk to the public is reduced by continuing sludge processing at the Defense Waste Processing Facility (DWPF) [4], no information is presented to support the amount of risk reduction achieved by continuing waste processing prior to completion of construction of the SWPF. Furthermore, insufficient information is presented to enable a comparison between the increased risks associated with disposing of Deliquification, Dissolution and Adjustment (DDA) and Actinide Removal Process (ARP)/MCU waste in saltstone with the risks associated with postponing treatment until all of the waste can be treated at the SWPF.

Similarly, although it is stated that it is necessary to treat waste with interim procedures prior to the completion of the SWPF because shutdown of the DWPF due to tank space limitations will be economically impractical, a comparison between the costs of shutting down and restarting the DWPF with the costs of implementing the proposed interim treatment procedures and disposing of higher activity waste in the SDF has not been provided. Although it was estimated that it would cost $1 billion to halt and restart waste processing with the DWPF [4], no basis for that estimate was given.

Path Forward: Provide a detailed cost/benefit analysis supporting a comparison of the proposed alternative with alternative treatment plans. The response should address the quantitative and qualitative costs and benefits of treating waste with the SWPF alone as well as the costs and benefits of treating waste with both the ARP/MCU and the SWPF. The response should include:

1) A comparison between the risks to the general public, workers, and inadvertent intruders associated with the proposed treatment plan and the two alternatives (e.g., treating waste with the SWPF alone or treating waste with the ARP/MCU and SWPF). The response should also include an estimate of the risk the tanks currently pose to the public as well as the number of tank-years of waste storage in old-style tanks that would be avoided by treating waste with DDA and ARP/MCU instead of waiting to treat waste with the SWPF (e.g., percent reduction). Consideration should be given to the fact that the wastes that have been proposed to be removed are the lowest activity wastes [4].

2) A comparison of the costs associated with at least three alternatives (i.e., the proposed alternative, treating waste at the SWPF alone, and treating waste with the ARP/MCU and SWPF). The response should address the costs associated with construction and operation of interim procedures and the costs associated with disposing of a higher activity waste on site, as well as the costs of ceasing and restarting sludge processing. Additional alternatives, such as slowing down the throughput of the DWPF or creating new interim tank storage, should be considered. The comparison should also consider factors other than economic cost (e.g., schedule) and the factors should be converted into a comparable metric (e.g., cost and risk) to the extent practical.

The analysis should reflect uncertainties in the timing of when sludge processing would need to cease due to lack of tank space and the uncertainty in the availability of the ARP, MCU, and SWPF treatment facilities.

11. Comment: Predicted removal efficiencies and the bases for predicted removal efficiencies for many of the highly radioactive radionuclides are not provided for each of the treatment schemes (i.e., DDA, ARP, MCU, SWPF). Predicted removal efficiencies and the bases for those removal efficiencies are necessary to support the conclusion that highly radioactive radionuclides have been removed to the maximum extent practical. It should be noted that NRC staff believes that “highly radioactive radionuclides” are those radionuclides that contribute most significantly to risk to the public, workers, and the environment.

Basis: DOE has identified several radionuclides, including I-129, Tc-99, Sn-126, Se-79, Cs-137, Sr-90, Pu-isotopes, U-isotopes, and Np-237/Am-241, as radionuclides that are important to the Saltstone Disposal Facility (SDF) performance [1, 3, 5]. However, the expected removal efficiencies of all of these radionuclides by the DDA, ARP, MCU, and SWPF treatments are not provided. Predicted removal efficiencies, with the technical bases for the predicted efficiencies, are necessary to support an evaluation of whether the proposed treatment plan is consistent with the removal of highly radioactive radionuclides to the maximum extent practical. Removal efficiencies for unit processes within each of the treatment processes (e.g., cross flow filtration, monosodium titanate (MST) strikes, and solid washing operations) are needed to support the predicted removal efficiencies for each treatment process. Estimated uncertainties in predicted removal efficiencies are necessary to allow a meaningful comparison of the predicted performance of each process and to support an analysis of the source term as part of a performance assessment.

For example, the concentration of several highly radioactive radionuclides in the waste from the SWPF will be higher than the concentrations resulting from the ARP/MCU treatment (Table 3-1 of [5]). Based on the information in Reference 4 and supporting documents, it is difficult to determine if the SWPF waste has higher concentrations of some radionuclides than the ARP/MCU waste because of differences in the predicted radionuclide concentrations in influent waste streams, or because the SWPF will have lower decontamination factors for some radionuclides than the ARP/MCU treatment.

Path Forward: Provide a list of radionuclides that are determined to be highly radioactive radionuclides with respect to waste disposal at the SDF. The response should include technical bases to support the selections. The determination of which radionuclides are highly radioactive with respect to waste disposal at the SDF should address the predicted contributions of each radionuclide to the risk to the public, workers, and the environment under expected conditions and under less favorable conditions (e.g., in cases with significant degradation of the cap, erosion barrier, or waste form).

Provide predicted removal efficiencies for highly radioactive radionuclides for the DDA, ARP, MCU, and SWPF treatment processes, as well as unit processes within each treatment process. The response should include flowcharts showing removal efficiencies for highly radioactive radionuclides. The response also should include estimated uncertainties in the predicted removal efficiencies.

12. Comment: Additional information about the selection and optimization of treatment steps in the DDA treatment process and the selection of waste for DDA processing is necessary to support the conclusion that highly radioactive radionuclides have been removed to the maximum extent practical.

Basis: Results of both DOE and independent NRC analyses indicate that several radionuclides (e.g., I-129, Tc-99, Sn-126, Se-79, Cs-137, Sr-90, Pu-isotopes, Np-237/Am-241) are important to SDF performance. Significant fractions of the inventory of most of these radionuclides at the SDF will be attributable to the DDA waste [5]. However, processes to minimize the concentration of many of these radionuclides in the DDA waste are not discussed in the waste determination or supporting documents. For example, attempts to minimize the amount of Sn-126 or actinides in DDA waste might include steps to minimize the amount of sludge entrained in the waste during the DDA process; however, the waste determination does not include a description of the variables that affect the amount of sludge that is entrained or any steps that could be taken to minimize the amount of entrained sludge.

Similarly, although the waste determination indicates that settling is expected to remove a “significant portion” of the insoluble radionuclides (pg. 15 of [4]), it is unclear what removal efficiencies are expected, what data there is to support the expected removal efficiencies, and how the process has been optimized. Because the expected removal efficiencies and factors affecting the removal efficiencies are not discussed, it is unclear whether additional treatment steps, such as filtration, would be practical or if currently planned treatment steps, such as settling, could be improved.

In Reference 4 it is indicated that the lowest activity waste will be selected for DDA processing; however, a comparison of the radionuclide concentrations of the wastes prior to processing is not provided.

Path Forward: Provide information to support the conclusion that the lowest activity waste will be selected for processing in the DDA. Provide information about the selection and optimization of treatment steps to minimize the concentration of highly radioactive radionuclides in DDA waste. The response should include a description of:

1) Factors that affect the amount of sludge entrained in the DDA waste, and efforts to optimize the process to minimize the amount of entrained sludge.

2) Alternative deliquification technologies that were evaluated and the expected removal efficiencies of highly radioactive radionuclides by those technologies. The response should address whether any technologies, such as vacuum techniques, that have been employed with some success at other sites (e.g., Hanford) were considered. This response also should address the potential effects of differences in the porosity and pore structure of saltcake in different tanks and the potential effects of these differences on the success of the deliquification processes.

3) Alternative filtration technologies that were evaluated and the

expected removal efficiencies of highly radioactive radionuclides by those technologies.

In addition, a detailed cost-benefit analysis of the alternative treatment technologies should be provided to support a determination of whether the proposed DDA process is consistent with the removal of highly radioactive radionuclides to the maximum extent practical.

13. Comment: Detailed technical information on technologies considered for the treatment of Tank 48 waste as well as a cost-benefit analysis that compares alternative treatment methods are needed to provide reasonable assurance that highly radioactive radionuclides will be removed to the maximum extent practical.

Basis: The proposed disposal strategy for Tank 48 waste is to dilute the Tank 48 waste with other low-activity waste prior to processing it into grout for disposal at the SDF (pg. 40 of [4]). This strategy will add an estimated 0.8 MCi to the grout, increasing its radioactivity by 30 percent. A detailed cost-benefit analysis describing the various methods of waste removal considered by DOE before selecting this preferred method for treating Tank 48 waste is needed to provide reasonable assurance that the highly radioactive radionuclides will be removed to the maximum extent practical.

Path Forward: Provide a description of the various methods of waste removal considered and reasons for selecting the preferred method for disposal of the Tank 48 waste. Include a cost-benefit analysis to show that the technology chosen represents the optimum solution for disposal of the Tank 48 waste.

14. Comment: Additional information is needed to support the conclusion that treating waste with the ARP only if Sr and actinide removal are needed for the waste to meet Class C limits is consistent with removal of highly radioactive radionuclides to the maximum extent practical and maintains doses ALARA.

Basis: The waste determination indicates (pg. 17 of [4]) that after the completion of the ARP, waste will only be sent to the ARP unit if Sr and actinide removal is necessary for the waste to meet Class C limits. However, no basis has been provided to support the conclusion that this approach is consistent with removal of highly radioactive radionuclides to the maximum extent practical or maintains doses ALARA. Evidence is necessary to support the conclusion that it would be impractical to send more of the waste to the ARP once the ARP is built or that the risk reduction that could be achieved by sending more of the waste to the ARP is negligible.

Path Forward: Provide the basis, including quantitative and qualitative costs and benefits, to support a decision that individual batches of waste will not need to be processed through the ARP process. Demonstrate that this approach is consistent with removal of highly radioactive radionuclides to the maximum extent practical and maintains doses ALARA. The response should address the risk reduction that would be achieved by treating more of the waste with the ARP as compared to sending only the waste that would not otherwise meet Class C limits. The response also should address the negative impacts of sending more of the waste to the ARP once it is built, such as monetary costs and potential impacts on schedule.

## WASTE CHARACTERIZATION

15. Comment: The basis for the amount of sludge entrained in waste processed through the DDA process is unclear. The uncertainty in the concentration of key radionuclides, particularly for the DDA waste stream, is not provided and the point estimates are not clearly reasonably conservative.

Basis: On page 3-8 of Reference 3 it is noted that the waste concentrations for Low Curie Salt are based on the assumption that 300 mg/L of sludge is entrained in salt solutions derived from salt processing. In Reference 6 it is noted that the salt waste in Tank 41H would contain more than 400 mg/L of entrained sludge. Concentrations of some radionuclides that strongly influence the results, including Sn-126, will be sensitive to the amount of sludge entrained. Page 44 of Reference 4 lists the concentration of TRU radionuclides in DDA waste as 64% of the limit, but it is unclear from the information provided what key assumptions may have been made in the derivation of this value. For the overall salt waste treatment process, uncertainty of 3 to 5 MCi is estimated for the total inventory (essentially all Cs-137), but uncertainty is not provided for other highly radioactive radionuclides that drive the risk.

Path Forward: Provide the basis for the amount of sludge (and its associated radiological composition) that will be entrained in salt solutions sent to saltstone. Provide the uncertainty in the inventory of highly radioactive radionuclides (e.g., Sn-126, Tc-99, Np-237, I-129, Se-79) in saltstone, considering uncertainty in: 1) settling removal efficiencies, 2) sludge entrainment during salt processing, 3) sludge radiological compositions, and 4) saltcake concentrations. The response should clearly indicate whether the information is from direct observation (therefore less uncertain) or indirect methods (therefore more uncertain). Provide a summary of the direct measurement data of the radiological composition of saltcake.

16. Comment: It is not clear why the concentrations of some of the most risk significant highly radioactive radionuclides, as reported in current waste inventory projections, are significantly lower than the concentrations reported in earlier projections even though the overall radiological composition

increased substantially.

Basis: Comparison of the nominal blend of waste in 1992 (pg. 2-66 of [1]) with the Low Curie Salt (LCS) solution in 2002 (pg. 3-8 of [3]) shows that the concentrations of most of the radionuclides in the LCS waste were expected to be significantly higher than they were in the nominal blend in 1992. However, the inventories for Tc-99, Se-79, I-129, and C-14 all decreased. In addition, the concentration of Sn-126 increased by a smaller amount than would be expected based on the increases in the inventories of other radionuclides. Tc-99, Se-79, I-129, C-14, and Sn-126 are most of the more risk significant radionuclides. Reference 7 indicates that the Tc-99 concentration projected for saltstone was 36 times larger than projected in Reference 5.

Path Forward: Provide an explanation for the evolution of the inventory of key radionuclides over time. Explain why the concentration of the radionuclides given above decreased substantially or did not increase in proportion to most of the radionuclides in the more recently estimated saltstone compositions [3, 5] as compared to the composition estimated in 1992.

## PERFORMANCE ASSESSMENT

### General

17. Comment: The results of software verification are not provided for some software routines (e.g., PORFLOW).

Basis: The 1992 performance assessment [1] indicates in Appendix F that results of verification and benchmarking shall be recorded in an appendix of the performance assessment report. However, these results are not found in an appendix to the report. In addition, some of the results presented earlier in the sensitivity analysis for vault release showed lack of convergence, which possibly indicates that the model was being applied outside of the range over which it was verified.

Path Forward: Provide a summary of the results of verification and benchmarking performed for software used in the performance assessment.

18. Comment: Quality assurance (QA) implementing procedures are not adequately described for data verification.

Basis: The models, processes, and decisions rely on a large variety of documents, as well as other sources such as databases. The quality assurance implementing procedures that have been applied to the work have not been adequately presented, nor have examples of the implementation of the aforementioned procedures been provided. Some values, such as inventory values, are the result of a number of calculations that are not easily verified. Additionally, a list of editorial comments and potential errata are found at the end of this request for additional information.

Path Forward: The QA implementing procedures applied to References 1-4 should be provided and summarized. The application of the implementing procedures should be demonstrated by providing appropriate document and data review packages.

19. Comment: It is not clear that the deterministic approach employed by DOE is reasonably conservative, and the sensitivity analysis is too limited to conclude that uncertainties have been adequately addressed.

Basis: Page 4-31 of Reference 1 indicates that part of the rationale for not performing a quantitative analysis of uncertainty is the inability to predict conditions in the future, especially beyond several decades. However, it is precisely in circumstances such as the ones described, when knowledge about the future evolution of the site or waste is limited, that an uncertainty analysis should be used to determine how significant the effects of the uncertainties may be. The sensitivity analysis provided is dispersed throughout the various reports, and different analyses pertain to different designs and different inventories. Therefore, interpretation of the results is difficult. Only limited consideration has been given to the combinations of uncertainties to evaluate in sensitivity analysis.

The objective of the performance assessment calculations is to quantitatively estimate the system performance for comparison to the performance objectives of 10 CFR 61, Subpart C. The sensitivity analyses should identify the assumptions and parameters that affect the quantitative estimate of performance by evaluating the effects of changing the values of input variables or changing model structures. Uncertainty analyses should provide a tool for understanding, in quantitative terms, the effect of parameter and model uncertainties. These uncertainties should be described by considering a reasonable range of conditions, processes, or events to test the robustness of the SDF in comparison to the performance objectives. For example, an uncertainty analysis should address how changes in important uncertain parameters, such as parameters relevant to the radionuclide source term, engineered barrier degradation, and infiltration rate, affect the performance of the overall disposal system.

In the performance assessment [1] and the special analysis [3], the sensitivity and uncertainty analyses are frequently presented in the form of qualitative arguments, including discussions of the rationale for selecting particular scenarios and parameter values.

Path Forward: Expand the quantitative sensitivity and uncertainty analysis and document it for the current design and radiological composition of the waste to demonstrate that compliance with the performance objectives of 10 CFR 61, Subpart C can be reasonably assured. DOE should consider evaluating select combinations of uncertainty in key parameters. For example: waste composition, $K_d$ values for radionuclides in waste and geologic materials, infiltration to the waste (gradual and/or discrete failure of the engineered caps upper and lower layers), soil-to-plant transfer factors, hydraulic properties of the waste and vault (saturated hydraulic conductivity and effective diffusivity), oxidation of a fraction of the waste, and hydraulic conductivity of the aquifer.

Because one purpose of a sensitivity analysis is to examine the importance of various assumptions, the response should address the degree of reliance on various assumptions identified in the response to Comment 1. For example, the response should address reliance on the full performance of the infiltration cap and gravel drain by illustrating the fraction of full performance necessary for the site to meet the performance objectives of 10 CFR 61, Subpart C as a function of time.

20. Comment: Evaluation of the impact of natural cycling of climates is not provided.

Basis: As indicated in NRC's NUREG-1573, the sensitivity of the results to the natural cycling of climates over the analysis period should be considered in a performance assessment for a low-level waste facility [8]. Changes in infiltration rates and depth to water table as well as fluvial erosion rates and degradation mechanisms or rates for engineered barriers should be considered.

Path Forward: Provide an evaluation of the potential impacts of the natural cycling of climates.

21. Comment: It is unclear how the potential contribution from multiple vaults has been considered.

Basis: Although it is stated that the dose to the groundwater receptor is evaluated at a point that is at least 100 m downgradient of the SDF, the exact location of the receptor with respect to the vaults is unclear. The saltstone disposal facility may contain up to 15 vaults. The contaminant plumes from seven or more of these vaults may overlap, depending on the orientation of the vaults and the projected groundwater flowpaths. In addition, Figure 3.4-7 of Reference 1 suggests that there may be a difference in the hydraulic gradient projected for individual vaults.

Path Forward: Describe how the impact from multiple vaults has been considered. Demonstrate that the 100 m location is the point of maximum dose down-gradient from the vaults.

22. Comment: The basis for the 10,000 year effectiveness of the gravel layer as an erosion barrier is not provided. It is unknown whether the erosion controls have been designed based on guidance (e.g., NUREG-1623 [9]).

Basis: It is assumed in the analysis that erosion will stop once the gravel layer at 91 cm below the ground surface is reached. However, no basis is provided to support the assumption that the gravel layer will be 100% effective from 1000 yrs to 10,000 yrs. This assumption is key because it is the basis for eliminating the agricultural intruder scenario. Doses from the agricultural intruder scenario could be significant. In Reference 1, the “best estimate” doses resulting from a waste with much lower activity than the DDA waste ranged from 50-110 mrem/yr. Furthermore, much of that dose resulted from consumption of plants contaminated with Tc, and the soil-to-plant concentration factor may have been too low (see Comment 56).

Path Forward: Provide the basis for the conclusion that the gravel layer will prevent erosion from the time it is exposed to 10,000 years after site closure. Alternately, if it is found that this conclusion cannot be supported, scenarios that were screened out on the basis of the performance of the erosion barrier should be reevaluated.

23. Comment: The current analysis may not have been adequately updated based on recommended changes to the hydraulic conductivity of the clay layer.

Basis: Reference 2 suggests that the hydraulic conductivity of the clay used in the 1992 PA was too small (7.6E-9 cm/s compared to ~1E-7 cm/s) resulting in simulated infiltration that was lower than would otherwise be expected. However, the 2002 Special Analysis [3] and the results in the waste determination [4] are based on the 1992 value for infiltration through the lower infiltration barrier.

Path Forward: Provide updated PA results that used the new value for hydraulic conductivity of the clay layers of the engineered cap or provide a basis for using the smaller value.

### Engineered Cap and Near Field

24. Comment: The technical evaluation of the performance of the engineered cap over thousands of years is incomplete. A number of items are not adequately addressed in the numerical simulations of the engineered cap to estimate infiltration to the wasteform. These include:

1) Heterogeneity and field-scale properties of emplaced materials
2) Temporal variations in precipitation (infiltration) that could result in dessication of the clay layer(s), especially when considered with erosion that results in decreasing thickness of the water balance portion of the cap
3) Uncertainty in moisture characteristic curve properties
4) Realistic combinations of near surface processes such as erosion and

biointrusion. Page 3-29 of Reference 1 indicates that the Florida Harvester Ant can be expected to burrow to a depth of more than 2 meters (5% of the time).

Basis: In the 1998 Addendum (Section 2-3 of the SRT-WED-93-203 attachment) [2], it is calculated that, in the case of degraded (fractured) saltstone, if the clay/gravel drain fails, the offsite drinking water dose will increase from 0.6 to 80 mrem/yr. The offsite drinking water dose calculated in Reference 5 is 6.8 mrem/yr. If a similar increase in the offsite drinking water dose were to occur if the clay/gravel drain were to fail given the higher inventories, it seems the performance objective may be exceeded by a significant margin. In addition, sensitivity analysis of the numerical simulation results of infiltration through the engineered cap is limited.

Much of the information used in the analysis is based on very limited information or literature sources (e.g., moisture characteristic curves). For instance, the values selected for gravel indicate that the curve selected represents the more drainable end of the spectrum. A conservative choice would be to select a curve from the less drainable end of the spectrum. In addition, the results in Figure A.1-11 show that the saturation under the vaults in the backfill are approaching values where the curve fit previously given for the moisture characteristic curve was not very good.

Path Forward: Technical basis is needed for the specific items found in the comment above. Sensitivity analysis of engineered cap performance should be performed considering the specific items found above (e.g., items 1 to 4). A diagram of water fluxes through discrete points in the engineered cap should be provided to aid in understanding of the simulations.

25. Comment: The PA does not address the likely impact of rill and gully erosion on the integrity of the cover system.

Basis: Surface soil erosion is conservatively estimated at 1mm/year for cropland surrounding the Savannah River Site (Section 3.1.3.5 of [1]). At this rate, the 0.76-m backfill overlying the upper moisture barrier will be eroded in less than 800 years; however, this assumption implies that erosion is uniform, and does not account for the localized and often more severe impacts of gully erosion. High-intensity storms, common in the southeastern United States, could initiate and propagate gullies deep enough to penetrate the cover system after the institutional control period. This could result in fast flow pathways to the vault and saltstone monoliths.

Path Forward: Provide the additional technical basis and analysis to indicate that rill and gully erosion has been effectively considered in the PA.

26. Comment: Information about the performance and analysis of the engineered cap is in some cases limited.

Basis: The text on page A-14 of Reference 1 indicates that only the end half of the upper barrier needs to be simulated; however, the lateral boundaries are assigned no-flow. It is not clear that this approach adequately captures the total moisture flow through and around the cap. There may be significant lateral flow from the half of the barrier that is not being simulated.

Text on page 6 of SRT-WED-93-203 in Reference 2 indicates that a factor of 13 change in the clay hydraulic conductivity only results in a factor of 2 change in infiltration, which is not intuitive.

Path Forward: Provide additional information that explains the analysis and results of the engineered cap simulations provided above.

27. Comment: Technical basis is required to support the decision to exclude degradation of the lower clay-gravel drain system from consideration in the PA.

Basis: In the report, it is noted that the assumption that the clay-gravel system remains intact is the sole nonconservative aspect of the fracture analysis of the saltstone wasteform (pg. 4-52 of [1]); however, no analysis is provided to justify adopting this nonconservative assumption.

The PA considers two distinct scenarios that affect the quantity of infiltrating water reaching the lower clay-gravel drain system that overlays the top of the concrete vaults. In the first scenario, the upper moisture barrier or cover system is assumed intact throughout the compliance period. In the second scenario, the upper moisture barrier is assumed completely degraded throughout the compliance period. When the cover system is intact, the water flux at the top of the lower clay-gravel drain system is 2 cm/yr. When the cover system is degraded, the water flux at the top of the lower clay-gravel drain system is assumed to be equal to the mean annual infiltration rate of 40 cm/yr. In the PA, these two scenarios are evaluated for the case where the vault and saltstone, which underlie the lower clay-gravel drain system, remain intact and for the case where the vault and saltstone are bisected by fractures that allow water to infiltrate through the wasteform.

The saturated hydraulic conductivity of the lower clay layer is assumed to be 0.24 cm/yr, which is greater than the saturated hydraulic conductivity of the intact saltstone ($3.14 \times 10^{-4}$ cm/yr), but less than the bulk saturated hydraulic conductivity of the fractured saltstone (cubic law estimate is approximately 107 cm/yr). Because the clay-gravel drain system is assumed to remain intact, and the saturated hydraulic conductivity of the clay layer (0.24 cm/yr) is less than the lowest water flux (2 cm/yr) to the drain system, the clay above the vault should remain saturated.

Under saturated conditions, flow to the vault and saltstone is controlled by the saturated hydraulic conductivity of the clay. If the saltstone is intact, the water flux is controlled by the saturated hydraulic conductivity of the intact saltstone. If the saltstone is degraded, the water flux is controlled by the saturated hydraulic conductivity of the clay layer.

The results of numerical and analytical models of water flow in the near-field environments show that the water flow to the vault and saltstone wasteform is 0.175 cm/yr, regardless of whether the saltstone is intact or is degraded by fully penetrating vertical fractures, because of the presence of the functioning lower gravel/clay drain system. If the saltstone is degraded and the clay-gravel drain system is degraded, the water flux through the saltstone should approach the natural recharge rate of the system. Note that this last case requires a more complex unsaturated flow assessment.

Path Forward: Provide the technical basis for the decision to exclude the scenario of a degraded lower clay-gravel drain system from the PA, or demonstrate that the degraded clay-gravel drain system will limit the water flux through the degraded saltstone to 0.175 cm/yr or less.

28. Comment: The model support for the engineered cap performance is not sufficient to justify the performance of the cap over thousands of years without active monitoring and maintenance.

Basis: Model support is not provided for the numerical modeling results [1] that suggest the near-surface engineered cap would maintain exceptional performance for thousands of years. Text on page 5-5 of Reference 3 indicates the infiltration is 1.75 mm/yr for 10,000 years, which is ~0.1% of precipitation at a humid site. A number of near-surface processes were not considered in the numerical simulations (see Comment 24). In addition to addressing the technical issues in the numerical modeling, the numerical modeling must be supported with additional information. While the level of performance of the engineered cap in the analysis may possibly be achieved with active monitoring and maintenance, active monitoring and maintenance cannot be relied upon after the institutional control period ends (100 years). Information (e.g., analogs, field studies, experiments) is not provided to justify the numerical modeling results.

Path Forward: Provide the model support for the simulated performance of the engineered cap to limit infiltration, in particular for time periods in excess of hundreds of years.

29. Comment: The technical basis for the persistence of the bamboo as an evapotranspiration barrier and for erosion control is not provided.

Basis: Bamboo is used in the design of the engineered cap to reduce infiltration through evapotranspiration and to limit erosion. Some types of bamboo flower and die, thereby a persistent colony is not established. Introduction of deeper rooting species of flora may result in disruption of the engineered cap. DOE's simulation results in References 2 and 3 suggest that meeting the performance objectives is sensitive to the presence and effectiveness of the engineered cap.

Path Forward: If credit is taken for the bamboo in the performance assessment, then address the persistence of the bamboo in limiting infiltration and the ingress of deeper rooting species of flora over the analysis period.

30. Comment: The physical removal of backfill soil due to erosion is not clearly reflected in the analysis of water flux through the engineered cover system for the degradation scenarios.

Basis: In the analysis of the degraded scenarios, cover degradation is considered only in terms of loss of the moisture diversion functionality of the upper moisture barrier by setting the upper flux boundary to the 40 cm/yr site infiltration rate. The physical domain adopted for the simulation of flow and mass transport beneath the upper moisture barrier (Section A.1.2.2 and Figure A.1-9 of [1]) does not indicate the physical removal (by erosion) of backfill, which produces this loss of functionality. The removal of backfill soil is expected to affect the flow paths and moisture distributions above the underlying clay/gravel drain system.

Path Forward: Provide the technical basis and analysis to demonstrate that the degraded scenarios have been appropriately simulated.

31. Comment: It is not clear that there is consistency of the simulated fractional release rates with the various leaching, durability, and lysimeter tests described in References 10-13.

Basis: Fractional release rates that were independently hand-calculated using the physical dimensions of an intact vault and the effective diffusion coefficients developed in site-specific experiments [10-13] are 2 or more orders of magnitude greater than the reported model-calculated values. It is not clear what processes or parameters in the numerical model are responsible for the differences.

Path Forward: Provide a comparison of the model-generated fractional release rates of $NO_3$, Tc-99, I-129, Se-79, Np-237 to those generated based on the results of leaching experiments and lysimeter studies (e.g., those provided on page 2-54 of [1]), applying the appropriate correction and normalization factors.

## Saltstone/Vault Degradation

32. Comment: Page B-6 of Reference 1 indicates that empirical relationships for concrete degradation were used. It is not clear how it was ensured that the conditions under which the empirical relationships were developed were appropriate for application to vaults at SRS.

Basis: The empirical relationships used to estimate degradation were based on systems and a range of conditions that may or may not be appropriate for the application to vaults at SRS. Application of empirical models outside of their developed range can be a source of significant error. For the empirical sulfate and magnesium attack model, it is not clear if potential sources of Mg and $SO_4$ different from current natural conditions were considered.

Path Forward: Justify that the empirical relationships used to estimate degradation are appropriate for the vaults at SRS. For the empirical sulfate and magnesium attack model, potential sources of Mg and $SO_4$ different from current natural conditions (consistent with expected land uses) should be considered.

33. Comment: Page 4-33 of Reference 1 indicates that the saturated hydraulic conductivity of slag saltstone has not been measured. Values for hydraulic conductivity and effective diffusivity of saltstone are based primarily on laboratory-scale samples.

Basis: The summarized Core Laboratories Report in Reference 2 provides data for saltstone, but does not specify if values were obtained for slag saltstone or how the samples were obtained and whether they were representative of field-emplaced conditions. Because of the scale of the saltstone vaults, the curing conditions (e.g., temperature and moisture) may be different from the conditions imposed on laboratory samples, resulting in differences in their physical properties such as saturated hydraulic conductivity. The saturated hydraulic conductivity of the slag saltstone is a key parameter because it can dictate whether the releases are advective or diffusive from intact saltstone. The sensitivity analysis for PORFLOW-3D demonstrates the high sensitivity of peak fractional fluxes to hydraulic properties of the saltstone and vault (pg. 4-35 of [1]). Peak fractional nitrate fluxes can be up to 100 times larger and many radionuclides would be expected to have similar behavior.

Path Forward: Provide the basis for the saturated hydraulic conductivity of slag saltstone and address the representativeness of the samples that were tested. Provide the basis that the values obtained on the laboratory samples are representative of field-achieved values.

34. Comment: The explanation for the observed behavior of effective permeability to liquid and gas for saltstone samples in the summarized Core Laboratories Report in Reference 2 is unclear.

Basis: The summarized Core Laboratories Report in Reference 2 provides data for saltstone for effective permeability to gas at residual water saturation that was 32,400 times higher than the specific permeability to brine. Similarly, the effective permeability of gas at residual water saturation to water permeability at trapped gas saturation was 157 times higher. The explanation that the results can be explained by drying of the saltstone during the gas injection, or the presence of a trapped gas saturation in the original preparation of the material is confusing. If the presence of trapped gas can explain the results, then the presence of trapped gas may have influenced the absolute permeability measurements.

Path Forward: Provide additional explanation for the observed behavior of effective permeability to liquid and gas for saltstone samples in the summarized Core Laboratories Report in Reference 2.

35. Comment: Measurements of the degree of saturation of slag saltstone in field-emplaced conditions have not been provided.

Basis: Field measurements of the degree of saturation of slag saltstone over time were recommended in Section 5.3 of Reference 1 to reduce the uncertainties related to the long-term performance of the saltstone disposal facility. As pointed out in the report, the release rate of saltstone is very sensitive to the degree of saturation because the unsaturated hydraulic conductivity is orders of magnitude less than the saturated conductivity.

Path Forward: Provide the basis for the degree of saturation of slag saltstone in field-emplaced conditions.

36. Comment: Additional information is needed to provide confidence that there will be no significant cracks or separation at the grout/vault interfaces along the inner surfaces of the vault.

Basis: The saltstone grout will be poured into the vaults in the SDF [1]. A loss of integrity or separation of the materials at the cured grout/vault interface could create a pathway for water infiltration and adversely impact the isolation of the waste from the environment.

Path Forward: Provide information to demonstrate that the cured grout/vault interfaces would not be hydrologically favorable pathways or that they have been studied and found to have no significant impact on waste isolation at the SDF.

37. Comment: The basis for performance of saltstone containing Tank 48 waste (TPB organics) is not provided. It is not clear what the basis is for the limit on allowable organic content in the Waste Acceptance Criteria (WAC) for the Saltstone Processing Facility (SPF).

Basis: Reference 4 (pg. 16) indicates that Tank 48 waste will be sent directly to saltstone without treatment, but that the waste from Tank 48 will be mixed with other streams of low activity waste so that the processing limits for allowable organic content at the SPF are not exceeded. The physical characteristics of saltstone and its durability with respect to the retention of radionuclides may be significantly different when produced with the organic material from Tank 48 waste. For example, biodegradation of an organic-containing wasteform could represent a degradation mechanism that has not been evaluated in the testing to date.

Path Forward: Provide the basis for the performance of the saltstone (including the physical properties) and provide the basis for the limit on allowable organic content in the WAC for SPF.

38. Comment: Table 2.3-1 in Reference 1 indicates a range of saltstone compositions over which acceptable saltstone can be produced. Toxicity Characteristic Leaching Procedure (TCLP) tests were performed on a range of samples, with acceptable results over the range but fairly significant differences in the magnitude of results between samples. It is not clear over what range of compositions the physical properties of saltstone was characterized.

Basis: The performance of the saltstone system can be sensitive to the hydraulic conductivity of the bulk material (unfractured) of the vault and saltstone as well as the effective diffusion coefficients of radionuclides. The pore structure of the material, in turn, is a primary determinant of these physical properties. The pore structure of a cementitious material can be greatly influenced by the proportions of major phases.

Path Forward: The compositions of the saltstone for which physical properties were determined should be provided. The justification that the physical properties of saltstone obtained are appropriate for the range of saltstone components shown in Table 2.3-1 should be provided.

39. Comment: The credit taken for the vaults must consider the high concentrations of sulfate expected in the pore fluids of the saltstone.

Basis: The vaults have been assumed to be a diffusive and flow barrier. The basis for the conclusion that the concrete vault will last for 10,000 years is unclear. Although analyses of concrete degradation (section 3.1.3 of [1]) are presented, sulfate attack from the waste is not addressed. On page 3-9 of Reference 1 it is stated “Measured concentrations of sulfate in the saltstone pore-fluid are about 25,000 mg/L (Malek et al. 1987). Such levels are high enough to cause sulfate attack from inside the vault. ... The task of predicting concrete degradation for this case is very complex, and has not been attempted here.” Such high levels of sulfate may be expected to result in significant attack.

Path Forward: Provide the basis for the credit taken for the concrete vaults, considering the potential sulfate attack from the waste. The task of predicting the concrete degradation in this case may be challenging, but amenable to experimental evaluation.

40. Comment: The calculations of the various degradation mechanisms do not provide

sufficient detail (e.g., the parameters used) to allow independent verification [1].

Basis: Pages 3-9 to 3-18 and B-6 to B-11 of Reference 1 provide a summary of degradation calculations and results and theoretical framework for the modeling, but do not provide the parameter values used to perform the calculations.

Path Forward: Provide the details of the degradation calculations that allow independent verification of the results.

41. Comment: The conceptual model for degradation of the saltstone is not clearly described.

Basis: The various degradation mechanisms assessed for the vaults suggest that some fraction of the saltstone can be degraded, and that a shrinking core model may be most appropriate to represent this type of process. The degraded portion of the saltstone would likely have oxidizing chemical conditions and allow much greater radionuclide mobility than intact saltstone would (e.g., both chemical and hydrological properties would be degraded). Model results are likely to be sensitive to small fractions of the saltstone being in a degraded state. Reference 14 suggests that Tc in a slag cement may be oxidized at a significant rate even if the bulk material does not experience significant degradation, due to diffusion of oxygen. Therefore, cracking and the evolution of cracking over time could have a significant effect on model results. The model of release from saltstone assumes that reducing conditions will be maintained over the 10,000 year analysis period. Smith and Walton [16] provides a conceptual model to estimate oxidation of a cementitious wasteform.

Path Forward: Provide the conceptual model for degradation of saltstone and radionuclide release. Provide any experimental or other evidence that saltstone will maintain a reducing environment considering that degradation (e.g., chemical and physical) is likely to be represented as a shrinking core type of process at exposed surfaces, and that oxidation may be significant even if the bulk material does not degrade significantly.

42. Comment: Provide the characterization information of the as-emplaced saltstone and vaults.

Basis: The presence of the slag in the saltstone can result in shrinkage and cracking during curing. Cracking can have a significant influence on transport from the wasteform and degradation of the wasteform. On page 3-18 of Reference 1 it is stated that the assumptions about crack frequency for the “degraded case” are based on observations from vault #1; however, saltstone has a different composition than the vaults.

Assumptions used in the calculations of flow through fractured vaults and saltstone include the occurrence of vertical fractures that fully penetrate the vault and saltstone, with a fracture width of 0.005 cm and a fracture spacing of 300 cm. The authors considered the assumptions to be conservative because the presence of fully penetrating cracks has not been established, and the new design incorporates measures to minimize cracking. However, the assumption that the cracks are fully penetrating and vertical is not necessarily conservative because a fully penetrating, vertical geometry limits the residence time of infiltrating groundwater and reduces the interaction of the water with the saltstone wasteform. It is likely that cracks with frequent branching, commonly observed in the fracture of ceramics and concrete, would occur in the saltstone. These branching cracks, along with microcracks that result from mechanical and chemical (e.g., sulfate attack) effects, could lead to higher radionuclide releases compared to vertical fractures.

Higher releases also would occur if the fractures were more closely spaced than the 300 cm assumed in the model. For example, the sensitivity of nitrate release to crack spacing is discussed in Reference 1 (Section 4.2.1.2). Furthermore, information to support the statement that the new design incorporates measures to minimize cracking is not provided.

Path Forward: Provide characterization information, including photographs (if available), of the vaults and saltstone. If the basis for the assumed degree of cracking in saltstone is observations of cracking of vault # 1, differences between the chemical and physical properties of saltstone and the concrete used in vault # 1 should be addressed. In addition, the ability to observe small cracks should be discussed. The possible implications of the existence of cracks that are too small to be observed should be addressed with respect to the hydraulic properties of saltstone as well as saltstone oxidation as described in Comment 41. The technical basis for the assumption of fully-penetrating fractures with a fracture spacing of 300 cm should be provided, or it should be demonstrated that the selected approach is conservative considering the reasonably conservative alternatives mentioned in this comment that could lead to higher releases.

43. Comment: The assessment of saltstone degradation is not sufficient. Justification is needed for the assumption that the saltstone degradation rate will be similar to the degradation rate of limestone.

Basis: Very limited basis is provided to support the conclusion that saltstone degradation will be minimal over 10,000 years. Three potentially important issues that were not discussed are the impact of radiation, the potential for ettringite formation, and the potential for chemical dissolution. Experience with a slag wasteform found that it did not survive irradiation [17]. Sulphate ions reacted with $Al_2O_3$ to form the ettringite expansive phase with solid volume increases that imposed large internal tensile forces on the wasteform which resulted in a dramatic failure mode, reducing the wasteform to powder over a period of weeks.

For the intruder scenarios, the degradation of the vault and saltstone are modeled by assuming they degrade at the same rate as carbonate rock (pg. 3-44 of [1]). The basis for this assumption is not discussed, although the composition of saltstone is different than the composition of limestone and these differences (e.g., in radiological properties, $Na^+$ concentration, and sulfate concentration) may lead to different degradation rates. A number of leaching tests have been conducted, but the time frames were relatively short (< 90 days). Experience by Allan and Kukacka [18] suggests that some mechanisms can result in noticeable impacts that may not be fully-captured in short-term leaching tests. It is acknowledged that many cementitious materials do not respond well to accelerated tests for a variety of reasons, which is why sufficient understanding is needed of the potential mechanisms.

No technical basis is provided to support the assumption that the saltstone does not degrade by chemical dissolution, which could enhance the flow of water and the release and transport of radionuclides and chemical contaminants. The release of radionuclides from the saltstone is dependent on assumptions regarding the mechanisms of degradation, in addition to the characteristics of the fractures through which flow and transport occur. In Reference 1 (Section 3.1.2), it is recognized that contaminants bound in the solid matrix of the wasteform are released into the pore fluid through the process of dissolution. The release rate model for a fractured vault and saltstone wasteform, however, does not account for the potential effect of dissolution of the saltstone matrix by advecting groundwater. Dissolution of the saltstone matrix would release more radionuclides and chemical contaminants to the saltstone pore fluid and also would increase the fracture-width processes that would enhance the release and transport of contaminants from the SDF. Depending on the chemistry and flow rate of advecting water, the contribution of dissolution reactions to the release rate can be significant.

Path Forward: An assessment of saltstone degradation should be provided, including direct evidence of the resistance to radiation damage, other processes that may result in ettringite formation, and chemical dissolution. The basis that saltstone will degrade to an insignificant degree or at a rate similar to carbonate rock should be provided.

## Hydrology

44. Comment: It is not clear that the saturated zone model has been appropriately calibrated.

Basis: The text on page 4-41 of Reference 1 indicates that the model is relatively insensitive to recharge; however, observations at the site suggest that water levels fluctuate primarily in response to changes in recharge [19]. The text suggests the model is very sensitive to hydraulic conductivity. However, the observations of water level fluctuations are driven primarily by recharge fluctuations not changes in hydraulic conductivity which is essentially a static parameter.

Path Forward: Based on the limited calibration performed, explain whether the model-predicted insensitivity to recharge is consistent with the observations of water level fluctuations. If necessary, recalibrate the model to be able to reasonably predict water table fluctuations in response to changes in recharge. Model calibration uncertainty should be addressed considering the results presented on page A-44 of Reference 1.

45. Comment: Sufficient information for the development of the multiplier of 9.5 E-9 yr/L found in Reference 2 ("Sensitivity/Uncertainty of Z-Area Radiological Performance Results with Respect to $K_d$") is not provided.

Basis: Comparison of values in Table 1 and the resulting values in Table 2 of the "Sensitivity/Uncertainty of Z-Area Radiological Performance Results with Respect to $K_d$" in Reference 2 suggest that the effective dilution area is much larger than the vault dimensions multiplied by the aquifer thickness for a conservative tracer.

Path Forward: Provide a description of the hydrological parameters and their values that are used to generate the multiplier of 9.5 E-9 yr/L.

46. Comment: Given the fractional release rates from the vaults, it is extremely difficult to reconcile the low predicted groundwater concentrations at 100 m given in the figures in Appendix C of Reference 1, especially for the fractured cases.

Basis: Assuming complete mixing of radionuclides released from the vaults into the aquifer given the reported fractional release rates, the saturated zone units would need to be many hundreds of meters thick in order to result in the dilution that would result in the reported groundwater concentrations at 100 m (Appendix C of [1]). However, Appendix E [1] indicates the units are approximately 10 to 30 m thick. For a conservative species like nitrate, the main processes affecting groundwater concentrations at the compliance point should only be dispersion and dilution.

Path Forward: Provide plots of the fractional release rates leaving the vaults, entering the water table, and arriving at the receptor location. Provide information that reconciles the numerical modeling results with basic physical parameters governing transport in the saturated zone.

47. Comment: The process for addressing heterogeneity in geologic properties in the PA, considering resultant horizontal aquifer velocity directly impacts dilution and transport of radionuclides, is not adequately described.

Basis: Table 3.3-2 of the 1992 PA provides point values that were selected from much broader ranges provided in Table 2.2-1. However, limited discussion is provided as to why the point values were selected and how they were reasonably conservative. Increases in hydraulic conductivity will result in decreases in contaminant concentrations at the compliance point from dilution but will decrease transport times.

Path Forward: Provide the projected variability in horizontal aquifer velocity. The uncertainty in hydraulic conductivities and gradients given on pages 2-28 and 2-29 of Reference 1 should be provided and addressed in the performance assessment.

## Geochemistry

48. Comment: Parameter values and supporting data are not available for some of the distribution coefficients used for groundwater pathway modeling [1].

Basis: Although $K_d$ values were used in the groundwater pathway screening analysis, $K_d$ values were provided only for radionuclides that were included in the groundwater analysis (Table A.1-2 of [1]). To evaluate the appropriateness of the screening process, it is necessary to evaluate $K_d$ values for radionuclides that were screened from the groundwater pathway as well as those that were included in the groundwater pathway.

Furthermore, selection of distribution coefficients for groundwater transport modeling is an exercise typically subject to uncertainty and to which model results can be quite sensitive. It is, therefore, important to understand how well-constrained the choices of $K_d$ values are to have confidence that the model will not underestimate contaminant mobility. Table A.1-2 of Cook and Fowler (1992) [1] contains a number of $K_d$ values based on site-specific data. NRC staff needs to review the reports from which the $K_d$ values were obtained because conditions under which the data were obtained will affect how applicable they are to a given transport model.

Path Forward: Provide all of the $K_d$ values that were used in the groundwater pathway screening analysis, including those for radionuclides that were excluded from further analysis based on the results of the screening analysis.

Provide the following references:

Hoeffner, S.L. “Radionuclide Sorption on SRP Burial Ground Soil: A Summary and Interpretation of Laboratory Data.” Internal Report DPST–84–799. Aiken, South Carolina: E.I. du Pont de Nemours and Company, Inc., Savannah River Laboratory. 1984.

Looney, B.B., M.W. Grant, and C.M. King. "Estimation of Geochemical Parameters for Assessing Subsurface Transport at the Savannah River Site—Environmental Information Document." DPST–85–904. Aiken, South Carolina: E.I. du Pont de Nemours and Company, Inc., Savannah River Laboratory. 1987.

McIntyre, P.F. "Sorption Properties of Carbon-14 on Savannah River Plant Soil." Internal Report DPST–88–900. Aiken, South Carolina: E.I. du Pont de Nemours and Company, Inc., Savannah River Laboratory. 1988.

49. Comment: The basis for the Se-79 distribution coefficient for concrete and saltstone in the performance assessment is not clear [1].

Basis: Se-79 is a potentially mobile contaminant in cementitious materials [20]. Selenium solubility and sorption properties are strongly dependent on oxidation-reduction conditions. A footnote to Table A.1-2 of Reference 1 states that the $K_d$ value of 7 mL/g used for Se-79 in concrete and saltstone was "based on apparent diffusion coefficient for sulfate." NRC staff could not find text explaining this derivation.

Path Forward: Provide the technical basis for the concrete and saltstone $K_d$ value for Se-79 used in the 1992 performance assessment.

50. Comment: Use of literature $K_d$ values for ordinary concrete mixtures to represent radionuclide mobility in saltstone requires further justification.

Basis: Saltstone does not have the composition of ordinary concrete. For example, saltstone pore water is expected to have much higher $Na^+$ and $NO_3^-$ concentrations than the pore water of ordinary concrete [15, 21]. However, the potential effects of this difference on the mobility of radionuclides for which adsorption is sensitive to ionic strength, including Cs, have not been discussed. Similarly, differences in the solid composition of concrete and saltstone may cause differences in radionuclide sorption. Justification is needed to support the use of the same $K_d$ to represent radionuclide mobility in both in saltstone and concrete (Table A-3 of [1]).

Path Forward: Provide a technical basis for the use of literature $K_d$ values applicable to standard cement environments to predict radionuclide mobility in saltstone. The response should address potential effects of differences between the composition of solid phases and pore water in saltstone and the composition of solid phases and pore water in the concrete studied in the cited literature. If it is found that literature values for $K_d$ in concrete cannot be used to represent radionuclide partitioning in saltstone, alternative $K_d$ values for radionuclides in saltstone should be provided, and the expected doses from groundwater pathways should be recalculated.

51. Comment: Additional information is needed to support the predicted solubility of Tc in saltstone pore water.

Basis: An effective $K_d$ for Tc was derived based on the solubility of $Tc_2S_7$ as calculated with the MINTEQ code (Appendix D of [1]). The MINTEQ calculations are based on the assumption that the concentration of Tc in saltstone pore water is constrained by equilibrium with the solid $Tc_2S_7$; however, no experimental evidence is presented to demonstrate that $Tc_2S_7$ is present in the slag saltstone. The calculated concentration of Tc in the pore fluid is very sensitive to the presence of aqueous sulfide, but no direct measurement of aqueous sulfide in saltstone pore fluids is presented. In addition, the MINTEQ calculations of Tc concentration are uncertain because of uncertainty in the thermodynamic data for $Tc_2S_7$ [22].

Furthermore, because the default MINTEQ thermodynamic database does not include Tc species, values used to calculate Tc solubility must be provided to allow evaluation of the geochemical model. Specifically, reactions used to model the formation of aqueous Tc species, stability constants for those reactions, and the thermodynamic solubility constant for $Tc_2S_7$ should be provided.

Path Forward: Provide evidence to support the assumption that a sufficient concentration of sulfide is present in the saltstone pore fluid and that solid $Tc_2S_7$ is present in the saltstone to constrain Tc concentrations to low values. An alternative approach is to assume equilibrium with the solid $TcO_2$, which is reasonably characterized [22]. Provide the reactions used to model the formation of aqueous Tc species, stability constants for those reactions, and the thermodynamic solubility constant used to model $Tc_2S_7$ solubility. Provide a justification for the aqueous species of Tc included in the chemical modeling. If no aqueous complexes of Tc were included, explain why the choice is justified and does not lead to an underestimate of Tc solubility.

52. Comment: It is unclear whether the saltstone pore fluid concentrations calculated using MINTEQ in Appendix D of Reference 1 are appropriate, because the activity coefficient model used is not valid at high ionic strengths.

Basis: The methods used by MINTEQ to calculate activity coefficients of electrically charged aqueous species are most applicable to dilute solutions and are only valid for solutions with ionic strengths of less than approximately 1 mole/kg$H_2O$ [23]. The saltstone pore fluids, however, have much higher ionic strengths. Solubilities and solution concentrations calculated with geochemical codes, such as MINTEQ, are dependent on the activity coefficient model used by those codes. Incorrect results may result if the activity coefficient model is used outside its valid range of concentration. In Appendix D of Reference 1, for example, it was noted that the MINTEQ results, which indicated that all nitrate and nitrite in saltstone occurs within the pore fluids, differed from the observed presence of solid hydrated aluminum and calcium nitrates identified by the x-ray diffraction (XRD) analysis of Malek, et al. [15]. The difference was attributed to the method used by Malek, et al. [15] for preparing saltstone samples for XRD analysis. An alternative explanation for the difference in calculated and measured concentrations is the extrapolation of the activity coefficient model and the thermodynamic parameters used by MINTEQ beyond their applicable ranges.

Path Forward: Use an activity coefficient model valid to high concentrations to calculate saltstone pore fluid concentrations. Computer codes that use activity coefficient models valid to high concentrations include the EQ3 code (Pitzer model option), PHRQPITZ, and the Environmental Simulation Program developed by OLI Systems, Inc. (Morris Plains, New Jersey).

53. Comment: The concentration of Tc in saltstone pore water and the effective distribution coefficient for Tc should be recalculated to reflect current conditions.

Basis: Because the effective $K_d$ for Tc is calculated based on the solubility of $Tc_2S_7$ (Appendix D of [1]), the effective $K_d$ is sensitive to the concentration of Tc in the saltstone. However, the effective $K_d$ value was not updated to reflect the Tc concentrations currently predicted to occur in saltstone made from DDA, ARP/MCU, and SWPF wastes. Thus it appears that the effective $K_d$ derived based on concentrations of Tc predicted to be in saltstone in 1992 (Appendix D of [1]) may be inapplicable to saltstone made with DDA, ARP/MCU, and SWPF wastes.

In addition, it is unclear whether differences between the expected salt feed composition and the salt feed composition used in the MINTEQ analyses (Appendix D of [1]) will have a significant effect on the predicted partitioning of Tc.

Path Forward: Calculate effective distribution coefficients for Tc in saltstone made from DDA, ARP/MCU, and SWPF wastes and the current feed composition, or explain why the distribution coefficient calculated in the 1992 PA (Appendix D) is appropriate to predict Tc leaching from each type of waste. If new values of effective $K_d$ values for each type of saltstone are calculated, the expected doses due to groundwater contamination with Tc should be recalculated.

54. Comment: Information about the uncertainty of the effective $K_d$ used to model Tc partitioning in saltstone is needed to evaluate the predicted release of Tc in saltstone and the resulting uncertainty in doses from the groundwater pathways.

Basis: The predicted Tc solubility is sensitive to the thermodynamic solubility constant assumed for $Tc_2S_7$ and the concentration of sulfide in the saltstone pore water (pg. D-11 of [1]). Because these values are both very uncertain (pg. D-11 of [1]), and because precipitation of Tc as $Tc_2S_7$

is a key factor in determining the potential concentrations of Tc in groundwater, the uncertainty in the effective $K_d$ of Tc in saltstone is needed to assess the uncertainty in potential groundwater contamination with Tc.

Path Forward: Provide an estimate of the uncertainty in the value of the effective $K_d$ for Tc used in the performance assessment modeling. The response should address uncertainty in the solubility constant for $Tc_2S_7$ as well as the sulfide concentration in saltstone.

55. Comment: The assumption that chemical conditions in the wasteform will remain reducing throughout the model period is not supported.

Basis: The saltstone formulation includes blast furnace slag in order to impose reducing conditions in the wasteform (pg. 2–52 and D–8 of [1]). The chief benefit of this additive is to immobilize Tc-99, which is characterized by low solubility and high sorption coefficients under reducing conditions. In the current assessment [1], it is assumed that reducing conditions are maintained for the entire performance period, and an effective $K_d$ derived for Tc under reducing conditions is used to represent Tc release from saltstone. However, measurements of the redox conditions of experimentally simulated saltstone indicate that the pore water in saltstone is actually oxidizing, perhaps because of the high $NO_3^-$ content [15]. Furthermore, the Tc (IV) species in reducing grout waste forms are not stable towards oxidation under aerobic conditions. As saltstone in the shallow vadose zone degrades, its reducing capacity could potentially diminish over time. Oxidation of the saltstone that could occur near surfaces and cracks could result in oxidation and release of Tc [14, 16].

Path Forward: Provide a technical basis for the assumption that reducing conditions will persist in saltstone throughout the period of performance. Provide any experimental evidence that the saltstone will be reducing and address the results of Malek et al. [15]. The response should address the potential effects of oxidation near cracked surfaces of the waste on Tc oxidation and mobility. The response also should address the potential effects of oxygen in soil gas on the saltstone and as a source of oxygen for water contacting the saltstone. Alternately, if it is determined that the effects of oxidation near waste surfaces exposed to subsurface gas or infiltrating water cannot be neglected, the model should be revised to incorporate the effects of oxidation on Tc release from saltstone and the performance assessment should be updated.

56. Comment: The soil-to-plant concentration ratio for Tc requires additional justification.

Basis: The soil-to-plant concentration ratio for Tc used in the agricultural inadvertent intruder scenario is based on the assumption that Tc in excavated waste spread on the land surface will be insoluble (pg. 4-47 and A-69 of [1]). However, excavated waste is expected to be present in small pieces. Once waste is excavated and spread on the land surface, Tc would be expected to oxidize and dissolve rapidly [16]. Therefore the modification of the soil-to-plant concentration ratio based on the assumption that the Tc is in an insoluble form appears to be inappropriate.

Furthermore, a generic literature value of 5 (pCi/g vegetation / pCi/g soil) was used as the basis for the soil-to-plant concentration factor [1]. However, the results of site-specific plant uptake experiments conducted with saltstone samples indicate that a higher soil-to-plant concentration factor may be appropriate [24]. It is unclear why a generic literature value has been used instead a value based on existing site-specific data. Because ingestion of contaminated plants is an important route for Tc uptake in the agricultural intruder scenario, the value for the soil-to-plant ratio requires further justification.

In addition, the interpretation of literature values for plant uptake factors in Reference 2 may not be consistent with the information in the original reports. In Reference 2, the results of Baes et al. [27] are represented by using the plant categories “forage” and “food” instead of “leafy” and “reproductive”. Baes uses the latter classifications, while in Reference 2 the former is used. The value for the reproductive component of plant intake is used in the calculations and is labeled the “food” component. However, approximately 10% of the plant intake would be expected to be in the form of “leafy” plants. Because the plant uptake factor is almost an order of magnitude greater for the leafy component than the reproductive component, the leafy component should not be excluded from the analysis if the results of Baes et al. are used as a basis for the soil-to-plant concentration ratio.

Path Forward: Explain whether Tc in waste that is excavated and spread on the land surface can be expected to remain in an insoluble form. The response should address the predicted rate of oxidation of small particles of waste that are exposed to the atmosphere and the consequent rate of Tc oxidation. Provide a comparison of the results of site-specific plant uptake experiments [24] with the generic literature value of the soil-to-plant concentration factor that was used in PA modeling [1]. The response should include the value of $K_d$ that is used to convert the results of Murphy et al. [24] to a soil-mass basis. If it is determined that Tc in waste that is excavated and spread on the land surface would be expected to oxidize and dissolve rapidly, or that the results of site-specific plant uptake experiments should be used instead of a generic value, a new value of the soil-to-plant concentration ratio for Tc should be provided.

57. Comment: The potential effects of organic chemicals in the Tank 48 waste and in unintentional contamination from the ARP and CSSX treatments on saltstone durability and radionuclide retention in saltstone should be explained.

Basis: Experiments of saltstone durability have been based on samples prepared with simulated saltstone solutions that did not include the organic chemicals present in Tank 48 waste or chemicals that could be unintentionally carried over from ARP or CSSX treatments. Thus the potential effects of these chemicals and their degradation products on saltstone durability should be discussed.

Furthermore, the organic chemicals in Tank 48, as well as the organic chemicals used in the ARP and CSSX process, were designed to react with metals. It is unclear whether tetraphenylborate present in Tank 48 waste, or monosodium titinate and calixarene molecules that could be unintentionally carried over from the ARP and CSSX process could interfere with the precipitation of $Tc_2S_7$ or result in the formation of radionuclide complexes that would have a higher mobility than the uncomplexed radionuclides. Consequently, the effects of chemicals in the Tank 48 waste and any chemicals unintentionally carried over from the ARP and CSSX processes on the retention of radionucldes in saltstone should be addressed.

Path Forward: Discuss the expected effects of the organics in Tank 48 waste on saltstone durability and radionuclide retention. Provide an estimate of the types and amounts of organic chemicals that are expected to be carried over from the ARP and CSSX treatments into saltstone. Discuss the potential effects of any solvents and extractants carried over from the ARP and CSSX treatments into saltstone on saltstone durability and radionuclides retention.

58. Comment: Distribution coefficients used in the PATHRAE analysis have not been presented.

Basis: DOE updated the groundwater transport pathway analysis in Reference 3 using the PATHRAE code. DOE argued that, with the exception of Np-237, the new analysis confirmed the radionuclide screening and groundwater concentration results of Reference 1. However, values for contaminant distribution coefficients used for release and transport modeling in PATHRAE were not provided [3]. Model results cannot be evaluated without this information. It is important to note that the newer analysis indicated Np-237 was significant to performance. In addition, Reference 1 used $K_d$ values for concrete and saltstone that, in light of later studies, may need to be reevaluated. In many cases, the concrete and saltstone $K_d$ values used in Reference 1 were higher than the recommended values for cementitious wasteforms from the later literature review of Reference 20. NRC staff needs to be able to determine which, if any, values were changed for the 2002 analysis and what values were used in 2002 for radionuclides not analyzed in 1992. In addition, the NRC staff needs to be able to evaluate how values differ between intact and degraded cases.

Path Forward: Provide the values and technical bases for distribution coefficients used for PATHRAE release and transport modeling and address how values were reevaluated in the light of post-1992 literature or site-specific studies. The response should indicate which values are based on site-specific information and which are from other sources. The response also should address how parameter selection ensured that contaminant mobility was not underestimated.

59. Comment: The composition of sediment interstitial fluids calculated using MINTEQ (Table D.4-1 of [1]) appears to be incorrect.

Basis: MINTEQ was used to calculate fluid compositions in sediments outside of SDF vaults to simulate reaction of the saltstone pore fluid with mineral phases (represented by quartz, kaolinite, gibbsite, and an iron oxide phase) in the unsaturated zone (Appendix D). The composition of the pore fluid, also calculated using MINTEQ, is tabulated in Table D.3-3, and the calculated composition of sediment interstitial fluid is tabulated in Table D.4-1. A comparison of Tables D.3-3 and D.4-1 indicates that the concentrations of all species are exactly the same in the two tables, with the exception of $Al^{3+}$ and hydronium ion (pH). The text in Appendix D.4.2 states that the pore fluid changed very little after reacting with the soil minerals. Aluminum concentration was reduced because of a small amount of diaspore precipitation. The results tabulated in Table D.4-1 are inconsistent with the high degree of disequilibrium between the saltstone pore fluids and the soil minerals. In particular, $SiO_2$(aq) in the sediment fluid should be higher than the 1 mg/L listed in Table D.4-1 due to the dissolution of quartz and kaolinite. The $OH^{-}$ concentration should be lower than the value given in Table D.4-1 because the pH was reduced to 7.32. Also, if calcite had precipitated, as is commonly observed in systems where cement pore fluids were exposed to atmospheric $CO_2$(g), the $Ca^{2+}$ concentration would be different from that given in Table D.4-1.

Path Forward: Confirm that the MINTEQ calculations of sediment interstitial fluid composition are correct.

60. Comment: DOE has not established the appropriateness of a distribution coefficient approach to modeling radionuclide release from the saltstone wasteform.

Basis: While acknowledging that wasteform dissolution and radioelement solubility limits are important aspects of radionuclide release, the saltstone performance assessment models employ equilibrium distribution coefficients to model radionuclide concentrations in pore fluids in contact with the wasteform [1, 3]. The distribution coefficient, or $K_d$, represents dissolved contaminant equilibrium sorption on the surface of the wasteform and, therefore, does not reflect wasteform dissolution or contaminant concentration control by solid phase solubility. This modeling approach, therefore, will not accurately simulate radionuclide release. For instance, if solubility control is in effect, radionuclide concentration will not decrease as inventory is depleted, as would be modeled by using a $K_d$. There is no *a priori* reason to assume that, given a bulk waste radionuclide content, contaminants will partition between solid and liquid according to a partition coefficient. DOE needs to demonstrate that its model will not underestimate rates and quantities of radionuclide release.

Path Forward: Provide a technical basis for the appropriateness of the distribution coefficient approach to modeling saltstone contaminant release.

61. Comment: Leaching from concrete and saltstone would increase the pH of infiltrating groundwaters and could result in the migration of a hyperalkaline plume below the vault. The presence of a hyperalkaline plume could affect the flow of water and the transport of radionuclides and contaminants from the SDF. These effects were not considered in the performance assessment of the SDF.

Basis: The chemistry of pore fluids in contact with cementitious materials is characterized by alkaline pH (>10) that can persist for thousands of years [25, 26]. The high pH and the low silica concentration associated with cement pore fluids could strongly alter the aluminosilicate minerals (quartz, clays) present in the underlying native soil, possibly affecting its hydraulic conductivity and sorption properties and the solubility of radionuclides and chemical contaminants. These effects could influence the transport of contaminants from the SDF.

Path Forward: Evaluate the potential importance of alkaline plume migration on the release, flow, and transport of radionuclides and chemical contaminants from the SDF or explain why it is not important.

## Intruder Analyses

62. Comment: The recent intruder scenarios [3, 4] do not evaluate potential water usage inside the 100 m buffer zone, even though it is assumed that a house is built inside the buffer zone. The approach is inconsistent with the NRC regulatory approach if there is a viable water source.

Basis: Intruder scenarios should be designed to assess the impact to receptors who may disrupt waste or otherwise reside at the disposal site. A higher dose limit (500 mrem/yr compared to 25 mrem/yr) is applied in the NRC regulatory approach that takes into account the reduced likelihood that dwelling construction, well placement, or other activities are undertaken directly in the area of waste disposal (inside the buffer zone) after the institutional controls end. Contaminated well water usage by the intruder cannot be neglected on the basis that it is evaluated for the public (non-intruder) receptor, because the public receptor is at a different location and may not be exposed to more strongly-sorbing contaminants due to longer travel times. Although Reference 1 indicates that drinking water from an onsite well should be considered in the agricultural intruder scenario (pg 3-42 and A-57), the drinking water dose for onsite well was screened based on low expected doses from drinking water from a well located 100 m from the vaults.

Path Forward: Include the groundwater pathway and associated pathways in the analysis of the doses to hypothetical intruders. Specify where the intruder’s well is assumed to be located. The response should address doses due to drinking water from an onsite well (i.e., a well within the 100 m buffer zone) or the response should demonstrate that doses from drinking water from a well outside of the buffer zone bound doses from drinking water from a well within the buffer zone.

63. Comment: The intruder scenario does not evaluate potential disruption of the engineered barriers (e.g., the lower infiltration barrier of the engineered cap) and associated potential increases in grout degradation and groundwater pathway doses.

Basis: As noted in Reference 2, the low dose from the drinking water pathway was determined based on the assumption that the waste is undisturbed. In an intruder scenario, the waste may be directly disturbed or the engineered cap may be disturbed by near-surface activities. Since some of the degradation mechanisms of concrete and saltstone may be sensitive to the flux of water and deleterious species, a significant increase in infiltration to the surfaces of or through the system may result in degradation of the vault and wasteform, as well as accelerated transport through the unsaturated zone.

Path Forward: For the intruder scenarios, evaluate the potential disruption of the engineered barriers and the associated impacts on the groundwater pathway doses.

64. Comment: Considering the uncertainties in long-term engineered cap performance and the long-term weathering rate of the grout, long-term intruder doses (> 1000 years) from direct disruption of the waste should be evaluated.

Basis: Analysis presented in References 1 and 3 suggest that intruder doses may be sensitive to exposure pathways (agricultural) and the amount of shielding present at the time of the scenario. The exposure pathways evaluated and the amount of shielding present are in turn dependent on the performance of the gravel layer in the engineered cap (see Comment 22) and the integrity of the saltstone and vault (see Comment 43). Maintenance of the physical integrity of the saltstone is the basis for excluding the well-driller intruder scenario for the entire 10,000 year performance period (pg. 57 of [4]). The performance of the gravel layer for 10,000 years is the basis for eliminating the agricultural scenario and for the amount of shielding in the intruder resident scenario.

Path Forward: Provide analysis of the long-term intruder doses from direct disruption of the waste. It should be noted that this is an acceptable mechanism to address technical issues and uncertainties discussed in other comments.

65. Comment: Two types of averaging are applied in the direct exposure intruder analysis that may not be appropriate considering the volume of waste to be disposed of.

Basis: Page 4-26 of Reference 3 indicates that “the use of the average concentrations of radionuclides in a disposal vault, rather than the maximum concentrations at any location in a vault, is appropriate when an inadvertent intruder would access a vault at random locations”. From a risk perspective, the statement is correct. However, the information provided in Reference 4 shows that each waste stream may in fact be different classes of waste (Class A, B, or C). Thus the risk from each type of vault should be provided, unless the waste streams are going to be mixed prior to emplacement in the vaults. The reduced likelihood of the scenario occurring is already accounted for in the application of a 500 mrem/yr limit to the intruder scenarios as compared to the application of a 25 mrem/yr limit to the nominal scenario. Use of the average concentration is not appropriately protective if the volume of more highly-concentrated waste would fill an area that is consistent with the exposure scenario. If the volume of waste is considerably smaller than the area used in the exposure scenario, then averaging would be appropriate. In addition, a dilution factor of 0.6 is applied to account for the probability of putting a house down on an area between vaults. As indicated with respect to waste concentrations, the likelihood of the scenario occurring is accounted for in application of the higher limit.

Path Forward: The full range of results for waste type and receptor location should be provided that would allow for comparison with the performance objectives of 10 CFR 61, Subpart C.

## Dose Modeling

66. Comment: The pathway screening procedure in Reference 1 was based on estimates of waste concentration in 1992. It is unclear that the pathway screening analysis was reevaluated in the more recent documents [3, 4] based on the updated waste concentrations.

Basis: The concentrations of many radionuclides in the projected waste composition in 1992 were significantly lower than projected concentrations in the Low Curie Salt evaluated in 2002 or the DDA waste evaluated in 2005. Pathways may have been eliminated based on the composition of waste in 1992 that would not have been eliminated based on the new waste composition.

Path Forward: Provide a revised pathway screening analysis based on current waste concentrations.

67. Comment: The argument for eliminating the biointrusion pathway in Reference 1 may no longer be appropriate.

Basis: In Reference 1, one of the arguments for eliminating the biointrusion pathway as an exposure pathway was that the other pathways would have a more significant contribution due to the disruption of larger quantities of waste. However, in References 3 and 4 these other more significant pathways have been proposed to be eliminated with the revised design, whereas the biointrusion pathway may not have been eliminated in the revised design, depending on the depth of cover provided and the degradation rate of the waste.

Path Forward: Reevaluate the biointrusion pathway in the current analysis, or describe why it is still considered appropriate to screen out this pathway.

68. Comment: The approach to eliminate exposure pathways is based on deterministic values of parameters such as $K_d$ values and $B_v$ values (soil-to-plant transfer factor). This approach is not adequate unless the parameter values are sufficiently conservative or supported by site-specific data.

Basis: The relative importance of the exposure pathways can be very sensitive to the parameter values selected in the screening process. As an example, the calculated result that the Tc-99 water pathway exceeds the vegetable pathway by a factor of 4 can change to 1/10 based on the selection of $K_d$ and $B_v$ within the range of natural variability.

Path Forward: For screening of exposure pathways, use sufficiently conservative parameters or site-specific data.

## EDITORIAL

1. Pg. 4-3 of [3]. Po-210 listed after Pb-210 should be Bi-210.

2. Pg. 6-2 of [3]. Is it the E-Area Disposal Facility?

3. Pg. 2-15 of [1]. The arithmetic mean for turbidity is outside of the range.

4. Pg. 2-43 of [1]. It is not clear that Tc-99 comprising 30.63% of the activity of the projected salt solution feed to saltstone is accurate considering its low specific activity.

5. Pg. A-10 of [1]. The scale on Figure A.1-5 has errors in the exponents.

6. Pg. A-40 of [1]. Table A.2-1 gives vertical hydraulic conductivities of 4E6 and 2E9 m/s. It appears the exponents are not correct.

7. Pg. A-40 of [1]. The effective diffusion in the saturated zone is estimated to be of 5E-6 cm/s. The units do not appear to be correct.

8. Pg. C-41 of [1]. Table C.4-3 lists a $K_d$ for Se-79 of 5 cm3/g which is not consistent with the value given in Table A.1-2.

9. Pg. E-23 of [1]. The values given in Figure E.2-8 do not appear to be consistent with the text given on page E-21.

10. Pg. 10 of SRT-WED-93-203 [2]. Footnote d indicates that the result of 0.6 mrem/yr includes the effect of an increase in the hydraulic conductivity of the clay as well as increased hydraulic conductivity and effective diffusivity of the concrete and saltstone. However, the text seems to indicate that the 0.6 mrem/yr result is for an increase in the hydraulic conductivity of the clay and a cracked vault, not the scenario indicated.

11. Pg. 3 of the OPS-DTZ-94-0001 letter in Reference 2 indicates that even if the facility degrades sometime in the future, the results would still be two orders of magnitude below the 4 mrem/yr groundwater protection standard. This seems to conflict with the results found throughout the addendum.

12. Although a value of 880 mL/g for the effective $K_d$ of Tc in saltstone is derived from chemical modeling (Appendix D of [1]), it is stated that a value of 700 mL/g was used in the performance assessment modeling (Table A-3).

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