NRC Staff Comments on the Draft Basis for Section 3116 Determination and Associated Performance Assessment for the F-Tank Farm at the Savannah River Site

Executive Summary

In accordance with the Ronald W. Reagan National Defense Authorization Act (NDAA) for Fiscal Year 2005, Section 3116, certain waste from reprocessing of spent nuclear fuel is not high level waste if the Secretary of Energy, in consultation with the Nuclear Regulatory Commission (NRC), determines that the criteria in NDAA Section 3116(a) are met. According to the Department of Energy (DOE), the "Draft Basis for Section 3116 Determination for the Closure of F-Tank Farm at the Savannah River Site" (DOE/SRS-WD-2010-001) (referred to herein as the waste determination) submitted to the NRC for review on September 30, 2010 demonstrates that those criteria (as specified below) are satisfied. The draft waste determination addresses stabilized residuals in waste tanks and ancillary structures (including integral equipment) at the time of closure.

In order to fulfill its consultative responsibilities, the NRC staff has reviewed the draft waste determination in conjunction with its review of the "Performance Assessment for the F-Tank Farm at the Savannah River Site" (SRS-REG-2007-00002 Revision 1 submitted to NRC on April 1, 2010 (referred to as Rev. 1 performance assessment or PA). The NRC review was conducted in accordance with NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations," Draft Final Report for Interim Use, August 2007. The review of these documents and supporting reference material conducted by a team of technical experts with expertise in earth and physical sciences as well as analytical modeling has led to a number of Requests for Additional Information (RAIs) and clarifying comments the responses to which will assist NRC staff with better understanding the bases for DOE conclusions in the waste determination.

The NDAA Section 3116(a) provides in pertinent part:

> *In General – Notwithstanding the provisions of the Nuclear Waste Policy Act of 1982, the requirements of section 202 of the Energy Reorganization Act of 1974, and other laws that define classes of radioactive waste, with respect to material stored at a Department of Energy site at which activities are regulated by a covered State pursuant to approved closure plans or permits issued by the State, the term "high-level radioactive waste" does not include radioactive waste resulting from the reprocessing of spent nuclear fuel that the Secretary of Energy (in this section referred to as the "Secretary"), in consultation with the Nuclear Regulatory Commission (in this section referred to as the "Commission"), determines –*

(1) does not require permanent isolation in a deep geologic repository for spent fuel or high level radioactive waste;

(2) has had highly radioactive radionuclides removed to the maximum extent practical; and

(3) (A) does not exceed concentration limits for Class C low-level waste as set out in Section 61.55 of title 10, Code of Federal Regulations, and will be disposed of –

(i) in compliance with the performance objectives set out in Subpart C of part 61 of title 10, Code of Federal Regulations; and

(ii) pursuant to a State-approved closure plan or State-issued permit, authority for the approval or issuance of which is conferred on the State outside of this section; or

(3) (B) exceeds concentration limits for Class C low-level waste as set out in Section 61.55 of title 10, Code of Federal Regulations, but will be disposed of –

(i) in compliance with the performance objectives set out in Subpart C of part 61 of title 10, Code of Federal Regulations;

(ii) pursuant to a State-approved closure plan or State-issued permit, authority for the approval or issuance of which is conferred on the State outside of this section; and

(iii) pursuant to plans developed by the Secretary in consultation with the Commission.

DOE concluded in its Draft FTF 3116 Basis Document, that the stabilized residuals within the waste tanks and ancillary structures, the waste tanks, and the ancillary structures (including integral equipment) located at FTF at the time of closure are not high-level waste pursuant to the criteria set forth in NDAA Section 3116(a). DOE noted that the Draft FTF 3116 Basis Document would be finalized after DOE completed consultation with NRC and, although not required by NDAA Section 3116, after public review and comment.

NRC staff has completed its initial review of the draft Basis Document and supporting performance assessment. NRC staff has drafted the following RAIs and clarifying comments to assist with completion of its review and development of a technical evaluation report which will document whether NRC staff has reasonable assurance that the NDAA criterion can be met for residual waste and related tank/auxiliary components at the FTF.

In summary, NRC has no comments on DOE's ability to meet Criterion 1 of Section 3116. NRC has several comments related to Criterion 2 including the following:

1. Insufficient information was provided on the approach used to identify, evaluate, test and implement alternative waste retrieval technologies including information on future plans associated with tank/waste types that have yet to be cleaned;

2. Insufficient information was provided on the decision process to be used to determine that highly radioactive radionuclides have been removed to the maximum extent practical; and

3. Insufficient information was provided on the relative costs and benefits of additional waste retrieval.

With respect to Criterion 3, NRC staff has developed a number of comments on the revision 1 PA that is the primary supporting reference to the waste determination with regard to DOE's demonstration of compliance with performance objectives in 10 CFR Part 61, Subpart C. While the primary purpose of NRC's initial review and comment on the Revision 0 PA conducted at the end of calendar year 2008 was to simply obtain a better understanding of DOE modeling approaches and results, NRC staff comments on the Revision 1 PA are focused on ensuring that sufficient model support exists for DOE's compliance demonstration. DOE made significant changes to its revised PA that addressed many of NRC's initial concerns with respect to (i) the assumed inventory and (ii) the uncertainty and sensitivity analysis. These include the following:

1. DOE elected to revise its inventory estimates upwards by an order of magnitude in most cases to address inventory uncertainty in the revised PA. NRC staff thinks this approach is more realistic and will help alleviate the risk associated with overly optimistic estimates of the success of waste retrieval activities for many of the tanks remaining to be cleaned in FTF.

2. DOE has made significant improvements to its uncertainty and sensitivity analysis that now clearly shows the linkage between the model results and important parameters and processes. DOE has also provided results of a new engineered barrier analysis that provides insights regarding important barriers to waste release and those factors most important to facility performance. While NRC staff has developed a few additional RAIs and clarifying comments regarding the extensive new information provided in the revised PA, these improvements to the PA are noteworthy.

Since the beginning of the scoping process for FTF that began in calendar year 2007, NRC staff has expressed concerns with the lack of coupling between individual submodels that comprise the PA. While a significant amount of time was spent discussing individual technical review areas and parameter values in the FTF scoping meetings, less time was spent discussing how all of the individual components that comprise the PA would be assembled to produce a technically defensible compliance case. While many of NRC's comments were considered and represented in the probabilistic analysis and significant improvements to the PA have been made as noted above, NRC staff still has a number of concerns in the following areas:

1. Lack of consistency of conceptual models and parameters used between PA submodels making it difficult to evaluate the realism and DOE asserted "conservatism" of the base

case (or compliance case) configuration (i.e., what may appear to be a conservative assumption in one model may not be conservative when combined with other models in the PA). Examples include the following:

a. Inconsistencies between model assumptions (e.g., importance of various degradation mechanisms) and parameter values (e.g., diffusion coefficients) between the cementitious material degradation and steel liner corrosion modeling.

b. Inconsistent treatment of the evolution of the tank system and relative timing of engineered barrier failures that significantly affects the magnitude and timing of waste releases from the tank.

2. Lack of consideration of the evolution of the engineered system and potentially overly simplified representation of the more complex and dynamic system being modeled that may lead to overly optimistic predictions of tank system performance. Examples include the following:

a. Lack of consideration of time varying properties of cementitious materials.

b. Simplified representation of the steel liner as a barrier to waste release--the barrier is currently treated as either being intact or failed with no releases occurring from the tank system during the compliance period for Type I and III/IIIA tank types in the base case configuration.

3. Lack of consideration of features, events, and processes that may significantly impact disposal facility performance but were either (i) not evaluated, or (ii) not considered in the compliance case. Examples include the following:

a. Calcareous zone dissolution that may provide conduits for fluid flow and by-passing of natural attenuation processes in the subsurface.

b. Potential wet-dry cycling of tank bottoms located within the zone of water table fluctuation.

c. Lack of consideration of existing leak sites and groundwater in-leakage into the tank systems that may lead to more aggressive service conditions than modeled in the base case.

While NRC staff certainly appreciates the complexity inherent in attempting to model the performance of the disposal facility over the 10,000 year compliance period and beyond, NRC staff thinks that additional information is needed to support DOE's compliance case. While some of NRC staff concerns are expected to be addressed during the RAI resolution process, other concerns can only be realistically evaluated over a longer time period than allowed for completion of NRC staff's Technical Evaluation Report in calendar year 2011. NRC staff expects that additional sampling and waste characterization, material property investigations, and other data collection activities will need to occur to provide adequate support for DOE PA models that may include (i) executing additional laboratory and field experiments, (ii) conducting expert elicitations, and (iii) performing additional modeling and calculations. NRC would like to initiate discussion with DOE regarding the types of activities that could be conducted to increase confidence that performance objectives can be met.

NRC's comments are binned and listed in order of decreasing risk-significance as follows: (i) requests for additional information or RAIs, (ii) clarifying comments, and (iii) editorial comments. RAIs and clarifying comments are binned by technical topic with a summary of the comments and their risk-significance provided at the beginning of each topical area. In general, responses to RAI comments are expected to impact NRC's conclusions with respect to Criterion 1, 2, or 3 (e.g., ability to meet performance objectives in 10 CFR Part 61, Subpart C), while clarifying comments are of lower risk-significance. Editorial comments are provided at the end of the document and do not require a DOE response; these comments are provided to help improve transparency and clarity of DOE documentation but are not expected to impact NRC's conclusions.

Criterion 1 (Waste Does Not Require Permanent Isolation in a Deep Geologic Repository for Spent Fuel or High-level Radioactive Waste) Comments

NRC has no comments on Criterion 1.

Criterion 2 (Waste has had Highly Radioactive Radionuclides Removed to the Maximum Extent Practical) Comments

NRC technical staff reviewed the waste determination as well as related documentation. The waste determination contains information related to DOEs approach to waste removal in Sections 2.3 and 5.2 as well as related information throughout the document and in supporting documentation as noted in the following requests for additional information. The staff found that information related to waste removal from Type IV tanks to be somewhat more complete and quantitative than information related to waste removal from the other types of tanks. While this is probably explained by the fact that there is much more experience upon which to base both expected and observed results, NRC staff believes that much of this experience could be employed to provide a more complete documentation of waste removal strategies for other types of tanks. Staff also considers that the Draft Basis Document should discuss the potential application of new enhanced waste removal technologies to address some of the challenges to be faced in waste removal from the more complex Type I, III and IIIA tanks.

RAI-MEP-1

Information on removal of highly radioactive radionuclides (HRRs) to the maximum extent practical (MEP) for Type I and III/IIIA tanks could be enhanced.

Basis:

On page 5-18 of DOE's waste determination with respect to cleaning Type I tanks, the waste determination states that "Experience in Tank 5 and 6 demonstrates DOE's successful deployment of innovative technologies capable of removing HRRs even under the most challenging conditions." Yet, no additional details regarding the effectiveness of the "innovative" technologies deployed in the cleaning of Type I tanks are provided. Because Type I tanks may provide the greatest configuration challenges due to the complex infrastructure and limited number of penetrations for access, information regarding the effectiveness of cleaning technologies in removing waste from these tanks is necessary for NRC staff to fully evaluate process effectiveness. With regard to waste, Type I Tank 7 also contains zeolite that may present additional challenges with respect to waste removal.

Likewise, information on cleaning technologies selected for Type III and IIIA tanks is lacking in the waste determination. DOE should provide an assessment of likely waste removal strategies and applications expected to be used for Type III and IIIA tanks given the challenges these tank types (and associated waste) pose compared to Type I and IV tanks (and waste).

Path Forward:

Provide additional details regarding the technologies selected for Type I tanks (and waste), as well as data on the effectiveness of technologies used to remove waste from Type I tanks to date (including technologies that may have been used in H-Area Tanks Farm (HTF) and are planned for use in F-Area Tank Farm (FTF)).

While NRC understands that plans are subject to change, DOE should provide as detailed a description as possible at this time, information on waste retrieval technologies expected to be deployed for Type I, III, and IIIA tank types (and associated waste) and the expected effectiveness of these technologies based on technology demonstrations and removal campaigns that have occurred to date (e.g., oxalic acid and feed and bleed campaigns discussed in the DOE Waste Processing Technical Exchange) including any sampling results that have been performed after tank cleaning (e.g., Tank 5). Discussion should include details regarding the specific challenges expected in cleaning the various tank (and waste) types, technologies or strategies that are expected to be used to overcome these challenges, and their expected level of success.

Reference

US DOE Office of Environmental Management Waste Processing Technical Exchange, Atlanta, Georgia, November 16-18, 2010.

RAI-MEP-2

Additional information regarding removal of HRRs to the maximum extent practical is needed for Type IV Tanks 18 and 19 that have already been cleaned.

Basis:

Insufficient detail to support DOE’s conclusion that HRRs have been removed to the maximum extent practical for Tanks 18 and 19 was provided in the waste determination. The scale of the y-axis on Figures 5.3-1 and 5.3-2 in the waste determination prevents meaningful evaluation of the effectiveness of volume reductions following bulk removal with more advanced cleaning technologies (e.g., ADMP and Mantis). Although Mantis was effective at removing waste from Tanks 18 and 19, the residual volume of waste remaining in the Type IV tanks is, nonetheless, risk-significant. Tank 18 contributes to the peak dose from Pu in DOE’s base case scenario leading to doses around 300 mrem/yr (3 mSv/yr) at later times beyond the period of compliance. The 0.2 to 0.3 volume percent of waste indicated on Figures 5.3-1 and 5.3-2 to remain in Tanks 19 and 18, respectively, is equivalent to around 2500 to 4000 gallons or 0.8 to 1.2 inches of waste remaining at the bottom of the tanks. As a basis of comparison, the initial Revision 0 PA estimate of residual inventory is based on an estimate that 1/16 of an inch or 0.06 inches of waste will remain in the tanks for those tanks that have yet to be cleaned. Revision 1 to the PA generally provides a more "conservative" value of 10 times the Revision 0 value or around 0.6 inches of residual waste expected to remain in most of the tanks yet to be cleaned[1]. Thus, information regarding the estimated residual volumes remaining in Type IV tanks that have been cleaned (and Type I tanks that have also been cleaned) is informative with respect to both (i) the expected performance of waste retrieval activities that will occur in the future, as well as (ii) the expected degree of conservatism of the inventory estimates provided in the revised PA.

Insufficient information is provided regarding the consideration of alternative technologies for HRR removal for Type IV tanks following the 1998, 2001, and 2002 campaigns that ultimately led to the selection of the Mantis technology. The technology selection process is important as indicated in WIR guidance, NUREG-1854 (NRC, 2007).

A number of factors that contributed to DOE's decision to discontinue Mantis operations are listed in the waste determination (page 5-17) with no corroborating evidence provided. Additional information is needed to allow NRC to independently evaluate the merits of DOE's decision to terminate removal operations using its selected technology.

A presentation by Savannah River Remediation (SRR) to DOE Savannah River and SC DHEC (SRR-CWDA-2009-00030) indicates that qualitative evaluations were conducted to reach conclusions regarding the practicality of additional removal and ability of Tanks 18 and 19 to meet 10 CFR Part 61, Subpart C performance objectives. SRR indicated that a more formal practicality basis would be provided in the Tanks 18 and 19 closure module. However, no details regarding the qualitative evaluation or plans for submitting a formal basis in the closure module were provided.

Path Forward:

Provide the following information:

1. Provide revised figures and a table of data pertaining to the information presented in Figures 5.3-1 and 5.3-2 to show the effectiveness of various cleaning technology deployments and campaigns at removing HRRs to the maximum extent practical, particularly those activities that occurred following bulk waste removal. DOE should provide sampling data or indicate when sampling data will be available to determine the relative volumes of various waste types remaining in the tanks (e.g., PUREX, zeolite, and coating waste) and effectiveness of the Mantis technology at removing residual wastes in Tanks 18 and 19. For example, data from Tanks 18 and 19 sampling and characterization was presented at DOE's Environmental Management Waste Processing Technology Exchange in November 2010.

2. Provide the formal systems engineering evaluation that led to the selection of the Mantis technology following the 2002 mechanical removal campaign, if one exists. Alternatively, DOE should elaborate on the process by which technologies are selected for implementation.

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[1] This is not true for the Type III tanks that are assumed to be cleaned to 1/16 of an inch or 0.06 inches.

3. Provide the following data used to determine that the Mantis was no longer effective at removing waste:

    a. Video and photographic evidence of remaining tank residuals over time (if available)

    b. Transfer line radiation readings

    c. Ratios of water to solids removed

    d. Additional details on equipment degradation

    Note: Some of this information appears to be provided in the presentation: SRR-CWDA-2009-00030. DOE should indicate if this presentation material should be relied on to support the Criterion 2 evaluation.

4. Explain the distribution of contamination remaining in Tanks 18 and 19 as depicted on Figures on Slides 34 and 37 of SRR-CWDA-2009-00030. DOE should indicate why the residual waste distribution differs between the two tanks, including information on the challenges encountered while retrieving waste from these tanks (e.g., especially recalcitrant waste remaining in specific areas of the tank), and why further efforts to remove residual contamination from these areas of the tanks is impractical.

5. Provide additional detail regarding its conclusion regarding the impracticality of additional removal of waste from Tanks 18 and 19, and provide a description of the process and timing for development of Tank closure modules for Tanks 18 and 19, as well as other tank sets.

References

NRC, 2007. “NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations, Draft Final Report for Interim Use” NUREG-1854, US Nuclear Regulatory Commission, Washington, DC. August 2007.

SRR-CWDA-2009-00030, 2009. “Proposal to Cease Waste Removal Activities in Tanks 18 and 19 and Enter Sampling and Analysis Phase.” Presentation by Ginger Dickert, Manager, Closure and Waste Disposal Authority, Meeting with DOE-SR and SC DHEC, October 1, 2009.

US DOE Office of Environmental Management Waste Processing Technical Exchange, Atlanta, Georgia, November 16-18, 2010.

RAI-MEP-3

Insufficient information is provided in the waste determination regarding DOE’s process for identification, evaluation, and selection of cleaning technologies for FTF tanks yet to be cleaned.

Basis:

While DOE (2003) provides a comprehensive evaluation of available technologies considering factors important to tank closure at the time of the report (e.g., cost and schedule), no recent information is provided regarding the technology selection process used to support DOE's demonstration of compliance with objectives embodied in Criterion 2 of Section 3116 of the National Defense Authorization Act (NDAA) for fiscal year 2005. If the current technology selection process is similar to that used in the 2003 report, DOE should explain how its technology selection process is consistent with NDAA criteria. DOE should also indicate how more recent information is considered in the technology selection process (e.g., technologies that have matured or been developed since issuance of the 2003 report). If the current technology selection process is different than that used in the 2003 report, then DOE should indicate the criteria by which technologies are identified and evaluated, and the process by which technologies are eventually implemented for a particular tank/waste configuration.

Path Forward:

Provide a comprehensive description of its current process for selection, evaluation and implementation of waste retrieval technologies to increase confidence that Criterion 2, removal of HRRs to the maximum extent practical will be met for tanks yet to be cleaned.

Reference

DOE, 2003. "Waste Removal, Balance of Program, Systems Engineering Evaluation Report," G-ESR-G-00051, Westinghouse Savannah River Company, Aiken, SC. September, 2003.

RAI-MEP-4

It is not clear that the technologies implemented to retrieve waste from Type IV tanks and that are under consideration for Type I and Type III/IIIA tanks will remove HRRs to the maximum extent practical. There is no clear linkage between the Criterion 2 demonstration and the revised PA results.

Basis:

While a comprehensive list of HRRs was developed for the purpose of developing a waste determination in 2010, it is not clear how HRRs were specifically considered when selecting cleaning technologies for tanks that have already been cleaned or how they will be considered in selecting technologies for future use. Furthermore, it is not clear how HRRs are considered when evaluating the practicality of additional removal. Footnote 39 of the waste determination indicates that no removal goals are set, yet cleaning methodologies are expected to collectively remove 99 percent of HRRs, based on a starting point of the maximum historical radionuclide inventory in the overall FTF, although individual tanks or ancillary structures may not achieve this level of HRR removal on an individual basis. NRC finds this approach conceptually acceptable. Yet, no information is provided to support the statement that 99 percent of HRRs are expected to be removed from the FTF. No information is provided on the starting point of the maximum historical radionuclide inventory in the overall FTF nor is it clear if this pertains to any single point in time, the total inventory processed over time, or how 1 percent of this maximum historical radionuclide inventory relates to facility risk.

Certain radionuclides may arguably present a significantly greater risk than other radionuclides to future human health (e.g., Tc, Pu). The PA results indicate that Tc will be co-precipitated with iron hydroxide/oxide phases yet no information specific to the FTF waste is provided to evaluate the percent Tc that is expected to remain in more soluble form and that portion of the Tc that is expected to be in more insoluble form (and in what phases) following mechanical and chemical cleaning (and limited support is provided for assumptions regarding how radionuclide retention will change over time due to the chemical evolution of the tank system). As explained in near-field comment RAI-NF-8, even a small percentage of readily soluble Tc remaining in the tanks following cleaning may lead to an exceedance of the performance objectives (e.g., if nearly 100 percent of the Tc is released, the PA predicts that a peak dose of 600 mrem/yr (6 mSv/yr) would result from its release). Tc-99 is expected to be present in significantly higher concentrations in Type I tanks.

Base case PA results also indicate that at longer time periods (around 40,000 years), Pu is expected to contribute significantly to the public dose (e.g., base case results show a peak dose of greater than 300 mrem/yr [3 mSv/yr]), with uncertainty analysis indicating that the dose from either Tc or Pu could approach much higher levels (>10,000 mrem/yr or >100 mSv/yr) within the compliance period albeit under what is considered by DOE to be very unlikely conditions. Oxalic acid may be relatively ineffective at removing Pu (West, 1980); however, no information is provided on how technologies are specifically considered with respect to their ability to remove key radionuclides such as Pu. The highest inventory of Pu is found in Type IV Tank 18 and is also present in significant quantities in other tanks that are subject to inventory uncertainty.

Considering uncertainty in the timing and magnitude of the peak dose, some radionuclides, tanks/components, and waste forms appear to pose a much greater risk than other radionuclides, tanks/components, and waste forms. Yet, it is not clear how this information was considered in developing a clean-up strategy to remove highly radioactive radionuclides to the maximum extent practical.

Path Forward:

Provide information regarding how HRRs have been or will be removed to the maximum extent practical. One approach would be to list the starting and final inventory for each HRR by tank/component and waste type for those tanks/components that have been cleaned including Tanks 17 and 20 to provide baseline information. DOE should list the starting and estimated final inventory for those tanks/components that have not been cleaned, and detail how specific technologies selected for implementation might reduce the risks associated with these HRRs. The starting inventory could be the maximum inventory for that tank/component; however, information on the expected starting inventory following bulk removal could also be provided (e.g., 10,000 gallons liquid waste remaining following bulk removal). As tanks will likely be cleaned in sequence with waste removed from one tank transferred to another tank, the information can be provided for tank/component groups to demonstrate removal of HRRs to the maximum extent practical for that group. Some effort should also be made to consider the cumulative effect of multiple tanks/components contributing to facility risk.

While NRC recognizes that HRRs may be removed to the maximum extent practical through cleaning technologies that accomplish bulk waste rather than selective radionuclide removal, DOE should make an effort to determine if technologies exist that are especially effective at removing HRRs from its waste tanks and determine if it is cost effective to implement these technologies. In some cases, factors such as expected solubility control may limit the potential benefit of additional waste removal. At a minimum, DOE should attempt to evaluate how its selected technologies perform with respect to its identified HRRs (e.g., ability of oxalic acid to remove Pu), particularly those HRRs that may pose significantly greater risk.

The Criterion 2 demonstration should have a clear linkage to the updated PA. DOE should also indicate how it optimized risk reduction for the overall tank system. Part of this optimization process could entail consideration of the potential benefits associated with removal of additional waste from certain tanks/components or waste types that are risk significant considering updated PA results.

Reference

West, W. L., 1980. "Tank 16 Demonstration: Water Wash and Chemical Cleaning Results," Memorandum to O.M. Morris, DPSP: 80-17-23, December 16, 1980.

RAI-MEP-5

The DOE process or strategy for considering developments in waste tank cleaning technologies that occur after the waste determination process has been completed is not apparent.

Basis:

In Section 2.3.7, it is stated that DOE will continue to review and consider technological developments relevant to waste tank cleaning and will evaluate technologies of comparable, or greater, effectiveness than those discussed in the waste determination. Several technologies were listed for potential evaluation including sluicing, mixing, chemical cleaning, vacuum retrieval techniques, mechanical manipulators, robotic devices, and processes that chemically extract radionuclides from residual material in the tank. However, the process or strategy for evaluating these technologies is not described. For example, what Savannah River Site (SRS) program or office monitors technological developments in waste tank cleaning, participates in DOE-system wide technology evaluation, and recommends new technologies for testing at SRS? What is the set of criteria used to determine whether a new technology should be tested or implemented at SRS? Without a process or strategy, there may be organizational resistance to the use of new technology that could significantly improve waste removal from the tanks.

For example, text on Page 2-61 of the waste determination indicates that as a result of the March 2006 DOE-sponsored Tank Cleaning Technical Exchange, a new waste tank tethered mechanical crawler-based cleaning technology was identified. DOE has adapted and successfully used this new technology in the unobstructed Type IV tanks. While this represents a success from the perspective that a new technology was identified and deployed to address closure of a subset of FTF tanks, it is not clear if these types of technology demonstrations are part of the overall DOE strategy used to identify new technologies and what other programs may be available to identify promising new technologies.

Path Forward:

Describe the DOE process or strategy that will allow for identification, evaluation, testing, and implementation of new waste tank cleaning technologies at SRS.

RAI-MEP-6

No information on the relative costs and benefits of waste retrieval was provided.

Basis:

Section 5.4 of the waste determination indicates that waste retrieval continues until "removal of HRRs is not sensible or useful in light of the overall benefit to human health, safety and the environment." However, no detailed information was provided regarding the actual criteria to be used in determining when highly radioactive radionuclides have been removed to the maximum extent practical. For example, no information regarding the relative costs and benefits of various cleaning technologies or additional waste retrieval was provided. As detailed in NUREG-1854 costs can include worker risks, financial costs, transportation costs, downstream waste impacts, schedule impacts, or environmental impacts. Potential benefits include averted long-term dose to members of the public, decreased worker risks in the future, decreased costs associated with clean-up of environmental resources, improvements in esthetics, etc. NUREG-1854 also recommends comparison of the relative costs and benefits associated with similar DOE activities.

For Tanks 18 and 19, DOE should provide information regarding the relative costs and benefits associated with current (completed) waste retrieval activities, alternative (additional) waste retrieval activities that might be implemented in the future, and complete tank exhumation. Although somewhat dated, DOE (2003) and DOE (2002) could be used to establish baseline technologies and costs from which these comparisons can be made.

Because some auxiliary components are located above ground surface, DOE should also evaluate the relative costs and benefits associated with complete removal versus cleaning of auxiliary components.

Path Forward

Using already available (e.g., (DOE, 2003) or (DOE, 2002)) or supplemental information, DOE should provide a more quantitative evaluation to demonstrate that removal of HRRs has or will proceed to the maximum extent practical based on the relative costs and benefits associated with current waste retrieval strategies, additional waste retrieval technologies that could be employed in the future, tank or component exhumation, and other similar DOE activities.

References

NRC, 2007. "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations, Draft Final Report for Interim Use," NUREG-1854, US Nuclear Regulatory Commission, Washington, DC. August 2007.

DOE, 2002. "High-Level Waste Tank Closure, Final Environmental Impact Statement," DOE-EIS-0303. May 2002.

DOE, 2003. "Waste Removal, Balance of Program, Systems Engineering Evaluation Report," G-ESR-G-00051, Westinghouse Savannah River Company, Aiken, SC. September, 2003.

Clarifying MEP Comments[2]

CC-MEP-1

Provide a figure similar to Figures 2.1-34, 2.1-42, and 2.1-43 of the waste determination for Type IV tanks.

CC-MEP-2

On page 5-16, Section 5.3 of the waste determination, DOE lists the following phases associated with waste retrieval activities: (i) initial technology selection, (ii) technology implementation, (iii) technology execution, (iv) technology effectiveness evaluations, and (v) additional technology evaluation. It is not clear when or how these phases are implemented (e.g., on a tank-by-tank or tank-type basis according to a pre-determined sequencing of tank closures). Additionally, there is no reference or detail regarding the characteristics or methodologies used in each of these phases. Provide additional detail on the schedule, methodology, and approaches used for each of these phases.

Similarly, it is not apparent that tank and waste types that may undergo a common sequence of bulk, salt, heel, and zeolite removal in the future were binned to facilitate the closure process. While a systematic and comprehensive approach to evaluating available cleaning technologies to target these tank/waste bins may be available, this type of information is not provided in the waste determination. Planning and process information is important to DOE's demonstration of compliance with Criterion 2 of the NDAA given the large amount of work remaining on tank cleaning and closure. DOE should provide a more complete description of its comprehensive strategy for tank closure including information on the expected schedule and binning of tank sets for cleaning technology selection, implementation and closure (e.g., grouting).

CC-MEP-3

Section 2.3.6 of the waste determination includes information on known leak sites in Tanks 1, 5 and 6 that may have led to contamination of the annular regions of these tanks. DOE (2003) indicates that annular regions should be sampled and if closure requirements can be met, no additional requirements should be pursued. Closure requirements in effect in 2003 are not necessarily consistent with MEP objectives.

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[2] Clarifying comments generally (i) seek clarification on DOE approaches to facilitate NRC's review of DOE's waste determination and supporting PA, or (ii) assist NRC with documenting the results of its review in a technical evaluation report. Given the lower, expected risk-significance of clarifying comments, compared to RAI comments, DOE's response is not expected to be as detailed as it would be for an RAI. However, it is also expected that in some limited cases, a clarifying comment might have been more appropriately labeled an RAI but insufficient information was available at the time to accurately judge the risk-significance of the comment. In these cases, it is anticipated that DOE will respond to the clarifying comment in a manner reflective of the risk significance of the comment.

Page 2-63 of the waste determination indicates that a magnetically mounted wall crawler was used to clean the external walls in Tanks 5 and 6; however, it is not clear that the vault floors of Tanks 5 and 6 were or will be cleaned. DOE should clarify its plans to clean the annular regions of the tanks at FTF to ensure that removal proceeds to the maximum extent practical. The annular regions represent areas of the tanks that are at a greater risk for early release. Furthermore, the relative costs versus benefits to remove what is expected to be readily soluble contamination from these regions of the tank system are not clear.

DOE (2003) also indicates leakage into secondary containment during waste removal will be acceptable to the regulators and the public. Mitigative actions to be taken included increased surveillance and procedural controls, increased readiness for annulus transfers within 24 hours, if needed, operation of the annulus ventilation system under negative pressure and recovery plans and procedures. It is also not clear if these procedures still apply or if DOE will consider removal of waste from annular regions contaminated due to leakage into secondary contaminant during waste removal operations as part of the demonstration of compliance with removal to the maximum extent practical criteria.

Reference

DOE, 2003. “Waste Removal, Balance of Program, Systems Engineering Evaluation Report,” G-ESR-G-00051, Westinghouse Savannah River Company, Aiken, SC. September, 2003.

CC-MEP-4

Page 2-64 of the waste determination indicates that flushing of transfer lines is routinely practiced to prevent build-up of waste and that specific design features are favorable with respect to waste accumulation. Additional details regarding the frequency and occurrence of routine transfer line flushing would be helpful. Furthermore, it is not clear from the waste determination if additional flushing to remove waste from the transfer lines will occur following decommissioning of transfer lines or if DOE is relying solely on its routine flushing practices to demonstrate removal to the maximum extent practical for transfer lines.

CC-MEP-5

No specific cleaning technologies to address zeolite found in Tanks 7, 25, and 27 were presented in the waste determination. DOE (2003) states that zeolite present in Tanks 18, 19, and 27 at FTF could be removed either with slurry pumps or a high pressure spray device. The zeolite in Tank 19 was found in a mound that was not disturbed by a slurry pump or Flygt mixer—the zeolite was broken up with a high pressure vendor supplied hydrolance. It is not clear if a similar approach will be used in other tanks. Tanks 18 and 19, which both contain significant quantities of zeolite, were recently cleaned with the Mantis technology; however, this technology is likely not viable for Type I and III/IIIA tanks due to tank obstructions that prevent its use. An oxalic acid dissolution demonstration conducted in Tank 24 (HTF) which dissolved about one-third of the zeolite in the tank was used to illustrate the problems that arise with using oxalic acid in tanks where significant quantities of zeolite are present (SRR-CWDA-2009-00030), although no specific information is provided regarding whether this technology could be used for tanks with smaller quantities of zeolite. DOE should clarify its plans with respect to cleaning tanks that contain zeolite.

Reference

DOE, 2003. "Waste Removal, Balance of Program, Systems Engineering Evaluation Report," G-ESR-G-00051, Westinghouse Savannah River Company, Aiken, SC. September, 2003.

SRR-CWDA-2009-00030, "Proposal to Cease Waste Removal Activities in Tanks 18 and 19 and Enter Sampling and Analysis Phase." October 1, 2009. Presentation by Ginger Dickert, Manager, Closure and Waste Disposal Authority, Meeting with DOE-SR and SC DHEC.

<u>Criterion 3 (The Waste Will be Disposed of in Accordance with Performance Objectives in 10 CFR 61, Subpart C) Comments</u>

<u>Waste Classification Comments</u>

Section 3116 of the NDAA for Fiscal Year 2005 requires DOE to determine the class of the waste it subjects to the waste incidental to reprocessing process for the sole purpose of determining whether clause (a)(3)(A) or (a)(3)(B) of Section 3116 applies. While waste class will not result in a potential compliance with NDAA criteria, this determination is important to NRC's understanding of the scope of its review. For example, greater than Class C (GTCC) waste subject to a WIR determination must meet Section (a)(3)(B) that contains an additional requirement not found in (a)(3)(A)—namely, it requires DOE to dispose of incidental waste pursuant to plans developed by the Secretary in consultation with the Commission
Waste classification comments request clarifying information related to exposure scenarios evaluated and additional information on waste classification for all waste tanks and components.

<u>Clarifying Comments on Waste Classification</u>

CC-WC-1

The text on page 6-5 of the waste determination summarizes the approach to modeling inadvertent intrusion in the PA. The text indicates that if a tank was encountered during drilling, the significant resistance afforded by the concrete and steel would result in termination of drilling operations. The waste determination indicates that this argument is presented as a basis for lack of consideration of a potential *chronic* drilling scenario for tanks at FTF in the PA. However, the text on page 6-8 of the waste determination indicates that the FTF probabilistic model was utilized to determine the dose to the *chronic* intruder assuming the 1-meter well contaminated source and one of three drill cuttings sources including a 3 inch-diameter transfer line, a 4-inch diameter transfer line, or a waste tank in calculating the site-specific factors for use in FTF averaging expressions.

1. Since chronic exposure from inadvertent intrusion into an FTF tank was not evaluated in the PA, NRC staff seeks confirmation that chronic exposures from inadvertent intrusion into a waste tank was in fact considered for the waste classification calculations as indicated on page 6-8 of the waste determination.

2. Since probabilistic results for chronic intrusion into a tank were not presented in the PA, additional details regarding execution and results of this scenario is needed to support NRC's review of the waste classification calculations (e.g., time v dose history plots for key radionuclides for waste classification and listing of important pathways and associated parameters). If chronic exposure to contaminated drill cuttings from inadvertent intrusion into FTF tanks was not considered, DOE should perform additional calculations for this scenario to inform waste classification.

CC-WC-2

DOE indicates that Tank 18 results were provided as this tank is the primary contributor to the peak dose in the FTF. The basis for this statement is not clear (i.e., does Tank 18 result in the largest peak dose due to groundwater-dependent pathways or due to direct pathways from contaminated drill cuttings). Peak dose for a groundwater pathway scenario under 10 CFR 61.41, for example, is not necessarily bounding for a well drilling intrusion scenario. Incomplete waste classification calculations were provided for auxiliary equipment (i.e., only transfer lines appear to be classified).

1. Waste classification is needed for all FTF tanks or a stronger basis provided for why the results presented for Tank 18 are bounding for all tanks.

2. DOE should also perform waste classification calculations for the Concentrate Transfer System (CTS), evaporators, pump pits, and auxiliary equipment. Only transfer lines were evaluated for waste classification purposes. Other equipment may be significantly more concentrated than residual contamination present in the transfer lines. Alternatively, an argument could be provided that the transfer line intrusion event bounds the impacts associated with other auxiliary equipment.

Other Waste Determination Comments/Recommendations

While DOE's PA provides most of the information to support the compliance demonstration for 61.41 and 61.42, the as low as is reasonably achievable (ALARA) objective is not specifically discussed in the PA but rather in the waste determination. NRC offers one comment related to DOE's demonstration of compliance with ALARA criteria. NRC also offers one comment related to tank system component grouting that may affect PA assumptions and the 61.41 evaluation. The waste determination also addresses compliance with the 61.43 and 61.44 performance objectives. NRC has no comments on the demonstration of compliance with these performance objectives, although several comments related to site stability (61.44) are found in the sections that follow that are also related to DOE's demonstration of compliance with 10 CFR 61.41 and 61.42 performance objectives.

While NRC does not require additional information in the waste determination that is otherwise reported in other supporting references, NRC reviewed the waste determination and also offers several recommendations to improve transparency of the document or provide additional information to the decision-maker that NRC thinks is important to the waste determination process.

Clarifying Comments on the Waste Determination

CC-WD-1

DOE should indicate whether it considered other design features that might be consistent with ALARA objectives in 10 CFR Part 61, Subpart C to mitigate potential disposal facility risks other than removal of HRRs to the maximum extent practical which only addresses inventory reduction.

CC-WD-2

On page 2-71 of the waste determination, DOE indicates that various pieces of equipment in both the primary tanks and the annulus will be grouted to the extent practical. The criteria to be used to determine the practicality of component grouting is not clear. DOE should

1. Indicate what equipment or components are not likely to be grouted and indicate why it is not practical to grout these components.

2. Indicate if any ungrouted equipment or components remaining in the tanks at closure would impact the PA assumptions and compliance demonstration (i.e., would lack of equipment or component grouting lead to potential conduits for fluid flow or lead to faster times to failure for engineered barriers due to the presence of steel and/or a potentially more aggressive service environment compared to what is considered in the base case).

Recommendations on the Waste Determination (CG/CSB)

1. NRC recommends DOE include additional information regarding its compliance case results in the waste determination. For example, DOE should consider reporting the peak dose over longer simulation times beyond the compliance period given uncertainties in the timing of peak dose. DOE should also consider providing additional uncertainty information (e.g., plots of dose versus time showing 5^{th}, median, and 95th percentile doses).

2. Given the level of expert opinion in developing the likelihood of alternate scenarios, NRC recommends that DOE also include additional uncertainty analysis information in the presentation of results for 61.41 for FTF (i.e., the presentation of each Configuration's (A through F) results independently with a qualitative discussion of the likelihood of each Configuration).

Inventory Comments

In January, 2009, NRC staff provided comments on DOE's Revision 0 FTF PA, SRS-REG-2007-00002, Revision 0, "Performance Assessment for the F-Tank Farm at the Savannah River Site," June 27, 2008. A subset of the comments related specifically to inventory is listed in Table IN-1 below. Previous NRC comments on DOE's Revision 0 PA included: (1) potential issues associated with the screening process used to select key radionuclides; (2) estimates of radionuclide inventories for those tanks that have been cleaned and sampled; and (3) the need for additional support for inventory estimates for those tanks that have yet to be cleaned. In general, NRC staff comments on DOE's Revision 0 PA inventory were addressed with exceptions noted in Table IN-1 and the text below.

In March 2010, DOE provided responses to NRC staff's comments on the Revision 0 PA, SRR-CWDA-2009-00054, "Comment Response Matrix for Nuclear Regulatory Commission (NRC) Comments on the F-Tank Farm Performance Assessment," March 31, 2010. Consistent with DOE's comment responses on inventory, the Revision 1 PA provided revised inventory estimates for residual wastes remaining in F-Area tanks for use in the PA. In general, inventory estimates were significantly (factor of 10) revised upwards to ensure that the inventories for key radionuclides are not significantly underestimated in the PA for those tanks that have yet to be cleaned.

Inventory estimates are risk-significant because inventory is directly related to dose for those radionuclides that are not solubility limited. For those radionuclides that are solubility limited, increased inventories may help ensure that mass is not depleted below solubility limits prior to final chemical transitions that lead to higher release rates from the contaminated zone.
NRC's new comments on inventory are related to apparent inconsistencies between the saltstone and FTF PA. For example, Ra-226 that grows in from Th-230 has recently been implicated as a key radionuclide of concern for the saltstone disposal facility. Because radioactive constituents in saltstone are derived from tank farm waste, it is not clear why Th-230 and Ra-226 are key risk drivers for saltstone, while these constituents are not assumed to be present in any significant quantity in the tank farms. Other comments are related to the accuracy of inventory estimates for Type IV Tanks 17-20 that have already been cleaned. For example, sampling results for Tanks 18 and 19 following more recent waste retrieval campaigns using the Mantis technology were not provided. Therefore, it is not clear that uncertainty in the final inventory for these tanks attributable to sampling uncertainty was appropriately accounted for in the PA.

To develop the following comments, staff reviewed SRS-REG-2007-00002, Rev. 1, "Performance Assessment for the F-Tank Farm at the Savannah River Site" (PA) and supporting documents provided to NRC by letter dated April 2, 2010 (Gutmann to Bubar). The staff's review criteria pertaining to radionuclide inventory in residual waste are contained in sections 3.1, 3.2, 4.2, 4.3.3, and 4.4 of NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007).

Table IN-1 Crosswalk of NRC Inventory Comments Resulting from Review of the Revision 0 PA to the New RAI Comments Based on NRC's Review of the Revision 1 PA

Old #	Subject	Adequate	Inadequate (Not Repeated)	Inadequate (New RAI #)	Note
IN-1	Key radionuclide list	X			
IN-2	Inventory of Tanks 18 & 19	X		CC-IN-1	Response was adequate but a follow-up clarifying comment was developed.
IN-3	Inventory of tanks cleaned with oxalic acid	X			
IN-4	Uncertainty in inventory	X			
IN-5	Inventory of tanks that contain zeolite	X			
IN-6	Initial inventory		X		Many errors and inconsistencies still exist with the tables and text. See editorial comments.
IN-7	Transfer line inventory--waste transfers		X		Response is inadequate but due to expected low risk-significance will not be repeated.
IN-8	Transfer line inventory--flushing model	X			
IN-9	Transfer line inventory--field survey results	X			

RAI-IN-1

Inconsistencies between the saltstone and FTF PAs with regard to the presence of Th waste should be resolved.

Basis:

Section 3.3.2 of Revision 1 to the FTF PA lists the screening process by which the FTF inventory was developed. Step 10 explains that the Ra-226 and Th-230 inventory was revised based on consideration of the age of the waste. Th-232 and Ra-228 were eliminated from the list of radionuclides assumed to be initially present based on special analysis. Based on the low inventory assigned to Th-230 and Ra-226 and the lack of inclusion of Th-232 and Ra-228, it is assumed that Th is not expected to be present in any significant quantities in FTF waste and that Th-230 is only included based on potential in-growth during the evaluation period (owing to its shorter half-life as compared to Th-232 which is not included in the initial inventory list). Yet, the saltstone PA indicates that Ra-226 (from Th-230 in-growth) is a primary risk-driver for the facility. As saltstone contaminants are derived from tank farm waste, and Th is not expected to be present initially in significant quantities for F-Area or H-Area tank farms based on the most recent documentation of inventories provided by DOE, the genesis of the Th waste in the saltstone disposal facility is not clear.

Path Forward:

Clarify if Th fuel was processed at the site or if Th waste was otherwise generated on-site. If Th fuel was processed at the site, clarify why Th-232 and Ra-228 were eliminated from the FTF inventory list. In general, additional details regarding the types of activities that took place on site and that generated waste that was subsequently stored in the FTF is needed to provide confidence that all potentially risk-significant radionuclides are considered in the PA.

Clarifying Comments—Inventory

CC-IN-1

It is not clear that inventory uncertainty was appropriately accounted for when estimating inventories for Tanks 17-20 (e.g., volume estimates and concentrations). Provide additional information regarding the expected break-down in uncertainty due to the following components: (i) uncertainty in measurements of the residual heel volumes, and (ii) uncertainty in the measured or estimated concentrations, and (iii) sampling uncertainty (i.e., uncertainty in the representativeness of samples due to variability). Because sampling data following Mantis waste retrieval operations in Tanks 18 and 19 were not used to develop the final inventory for these tanks and the concentrations of key radionuclides may be significantly different following Mantis technology deployment, it is not clear that a factor of 2 uncertainty range is sufficiently bounding for these tanks. Provide additional information to support the inventory estimates used in the base case and bounding inventory used in the probabilistic analysis for Tanks 17-20. For example, recent sampling data available for Tanks 18 and 19 following Mantis technology deployment could be provided and compared to the inventory estimates used in the PA for these tanks to show that key radionuclide inventories were not underestimated.

CC-IN-2

To account for uncertainty in the Revision 1 PA inventory estimates, a factor of 10 increase in the inventory was applied to most tanks yet to be cleaned. However, this adjustment does not appear to have been made for Type III tanks. Confirm that no adjustment was made for the Type III tanks. If no adjustment was made, provide a basis for the inequitable treatment between tank types.

Infiltration and Erosion Controls

DOE evaluates the performance of engineered surface barriers in its PA, which will be designed to limit the amount of water infiltration into the waste tanks. Water infiltration is usually a very sensitive parameter value in performance assessments, because it is directly related to the flux of contaminants into groundwater. DOE asserts that the closure cap has minimal impact on peak doses since the infiltration rate through the closure cap has reached a steady state value prior to steel liner failure (i.e., the risk significance of the closure cap is dependent on the performance of additional engineered barriers). While NRC agrees that the cover is oftentimes a redundant barrier, barrier analysis results presented in Section 5.6.7.3 of the revised PA indicate that the closure cap can become important as an independent barrier under certain conditions (e.g., cases 2, 3, and 4, which differ only by the assumed performance of closure cap, can result in significantly different fluxes indicating the potential importance of the closure cap for certain tanks and radionuclides if other barriers fail). As discussed in several near-field comments, the degree of conservatism of the assumptions regarding the steel liners and other engineered barriers is unclear. Thus, the low risk significance of the closure cap may be misleading if the assumptions regarding the additional engineered barriers are determined to be overly optimistic and more reliance is placed on the closure cap for performance. The closure cap assumptions may also be risk-significant for relatively short-lived radionuclides that may be released earlier in the compliance period from auxiliary equipment and components under certain conditions. While many of the DOE responses to NRC comments on the Revision 0 PA were not deemed responsive, these comments were not repeated (see Table IE-1 below). Instead, three new RAI comments related to the assumptions in the engineered closure cap performance and degradation modeling that affect the timing and magnitude of net infiltration over time were developed. These comments include (i) concerns regarding negative impacts associated with saturation of the surface layers with respect to cover stability and performance, (ii) lack of consideration of filter fabric degradation that may lead to earlier failure of the lateral drainage layer, and (iii) lack of justification for the apparent limit on infiltration rates for the degraded cover. One new clarifying comment related to cover component placement is also provided.

To develop the following comments, staff reviewed the PA and supporting documents provided to NRC by letter dated April 2, 2010 (Gutmann, 2010). The staff's review criteria pertaining to infiltration and erosion controls are contained in Sections 4.2, 4.3.1, 4.3.2, 4.4, and 4.6 of NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007).

Table IE-1 Crosswalk of NRC Infiltration and Erosion Comments Resulting from Review of the Rev. 0 PA to the New RAI Comments Based on NRC's Review of the Rev. 1 PA

Old #	Subject	Adequate	Inadequate (Not Repeated)	Inadequate (New RAI #)	Note
IE-1	Factors affecting the performance of the engineered closure cap	X			
IE-2	Seasonal, transient, and climate change impacts on cover performance.		X		Averaging of simulations creates a single, non-real result and less probable but more extreme events are minimized. Individual simulation results may be unrealistic (e.g., 42 in/yr of evapotranspiration).
IE-3	Effectiveness of erosion barrier for 10,000 years		X		The comment asked for additional support for the effectiveness of the erosion barrier for 10,000 years in light of biological degradation.
IE-4	Constant hydraulic conductivity of the intact combined layer		X		Time-invariant hydraulic conductivity of the combined layer is unsupported, but due to low risk significance will not be repeated.
IE-5	Drainage system design	X			Comment provides recommendation for final design. NRC will document DOE's commitment in TER.
IE-6	Erosion barrier—rock durability.	X			Comment recommends DOE consider NUREG-1757 guidance regarding rock durability. NRC will document DOE's commitment in TER.
IE-7	Erosion barrier—rock size, erosion layer thickness, and rock source evaluation.		X		Comment recommends a preliminary evaluation for a 10,000 year erosion cover design. DOE indicated that this will not be conducted until the final closure cap design.
IE-8	Pine root characteristics—include references.		X		Additional references were not provided, but the RAI will not be repeated.
IE-9	Root size changes—inconsistency in treatment.		X		It is not clear that roots will enlarge with growth in the lateral drainage layer but not in the underlying geomembrane.
IE-10	Infiltration rate increase due to lateral drainage layer or HDPE holes. Recommends sensitivity analysis to cover components.		X		DOE did not address the significance of the decreasing hydraulic conductivity of the drainage layer versus the holes in the HDPE with respect to infiltration. Sensitivity analysis on cover components was not performed but is still recommended.

RAI-IE-1

The PA should evaluate the potential implications of saturated conditions above the lateral drainage layer for the recommended closure cap Configuration #1a.

Basis:

Response IE-1 indicates that the performance of the lateral drainage layer dictates the moisture content of the above layers. Furthermore, table 80 within the report "*FTF Closure Cap Concept* *and Infiltration Estimates*" (WSRC-STI-2007-00184, Rev. 2) appears to indicate that at greater than 1,000 years the lateral drainage layer is unable to remove a large portion of the infiltrating water, the system saturates above the filter fabric layer, and runoff increases. If saturation occurs, pore pressure build-up in the overlying closure cap layers could directly affect cover stability, vegetation, hydraulic performance of cover materials, erosion, etc.

Path Forward:

Due to the potential risk significance of the closure cap and the ramifications of saturated cover conditions on cap performance, the PA should (i) provide the saturation for individual cover layers with respect to time, (ii) provide the average head on top of each layer for all time periods, and (iii) consider the effects of closure cap saturation on stability, vegetation, erosion, and the performance of cover materials under hydrostatic pressure.

Reference

Phifer, M.A., 2007. "FTF Closure Cap Concept and Infiltration Estimates," WSRC-STI-2007-00184, Revision 2, Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. October 2007.

RAI-IE-2

The PA should include a technical basis for the long-term performance of the geotextile filter fabric and the lateral drainage layers.

Basis:

The geotextile filter fabric and the lateral drainage layers appear to reduce infiltration through the closure cap by shedding water prior to contacting the GCL and limit runoff (as indicated in RAI-IE-1). Consequently, these layers affect the timing and magnitude of the infiltration through the closure cap.

The performance of these layers is subject to degradation of the filter fabric layer and the subsequent infilling of the porosity within the lateral drainage layer. As stated in the report "*FTF Closure Cap Concept and Infiltration Estimates*" (WSRC-STI-2007-00184, Rev 2), "sufficient data is not currently available to estimate the service life of the filter fabric" but that "it will degrade due to oxidation and root penetration". Calculations were presented in Appendix I that account for the reduction in hydraulic conductivity of the lateral drainage layer due to the migration of colloidal clay into the lateral drainage layer. However, no justification for lack of consideration of conveyance of larger particles from the middle backfill into the lateral drainage layer as degradation of the filter fabric progresses is provided. If the hydraulic conductivity of the lateral drainage layer decreases more rapidly than anticipated, infiltration through the closure cap could increase at earlier time periods.

The magnitude of infiltration also appears to be dependent on the performance of the geotextile filter fabric and the lateral drainage layer. Due to infilling from the overlying middle backfill, the hydraulic conductivity of the lateral drainage layer is decreased linearly with time to the midpoint between the middle backfill and lateral drainage layer. The physical basis for averaging the hydraulic conductivity of the two layers is unclear. If the hydraulic conductivity of the lateral drainage layer is less than what is predicted, infiltration may be greater than predicted by the HELP model.

Path Forward:

Provide a basis for (i) lack of consideration of filter fabric degradation that may lead to the migration of particles larger than colloids from the overlying middle backfill to the lateral drainage layer and earlier lateral drainage layer failure times and (ii) the averaging of the hydraulic conductivities of middle backfill and the lateral drainage layers.

Reference

Phifer, M.A., 2007. "FTF Closure Cap Concept and Infiltration Estimates," WSRC-STI-2007-00184, Revision 2, Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. October 2007.

RAI-IE-3

The maximum infiltration through the GCL from 1,800 to 10,000 years appears to be constrained to 12.45 in/yr in the HELP simulations.

Basis:

Even-numbered Figures 62-70 in the report "*FTF Closure Cap Concept and Infiltration Estimates*" (WSRC-STI-2007-00184, Rev 2) indicate an upper limit to the infiltration through the GCL at 12.45 in/yr. It is not clear what closure cap layer(s) provide this constraint. If the limit of 12.45 in/yr is a numerical constraint imposed by the HELP code, then the average infiltration may be greater.

Path Forward:

Provide a technical basis discussing the closure cap layer(s) that provide the apparent 12.45 in/yr cap on net infiltration in the HELP simulations.

Reference

Phifer, M.A., 2007. "FTF Closure Cap Concept and Infiltration Estimates," WSRC-STI-2007-00184, Revision 2, Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. October 2007.

Clarifying Comments—Infiltration and Erosion Controls

CC-IE-1

WSRC-STI-2007-00184, Rev. 2 discussed the installation quality of the geomembrane as "Good"; however, the HELP model also requires the specification for the placement quality of the geomembrane. The Help model input data in Appendix J of WSRC-STI-2007-00184, Rev. 2, listed the geomembrane placement quality as a "2". According to the "HELP User's Guide for Version 3" (Schroeder et al., 1994), an entry of 2, "assumes exceptional contact between geomembrane and adjacent soil that limits drainage rate (typically achievable only in the lab or small field lysimeters)." Provide the technical basis for selecting the placement quality of the geomembrane.

References

Phifer, M.A., 2007. "FTF Closure Cap Concept and Infiltration Estimates," WSRC-STI-2007-00184, Revision 2, Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. October 2007.

Schroeder, P. R., Lloyd, C. M., Zappi, P. A., and Aziz, N. M. 1994. The Hydrologic Evaluation of Landfill Performance (HELP) Model User's Guide for Version 3. EPA/600/R-94/168a. Office of Research and Development, United States Environmental Protection Agency (EPA), Cincinnati, Ohio. September 1994.

Near-Field

This section contains comments on the abstraction for the waste release model in the near-field environment of the FTF tanks. DOE abstracted (i.e., simplified) the tank system located in the vadose zone at FTF using the PORFLOW model for the base case. In addition, uncertainty and sensitivity analyses were conducted using the GoldSim modeling platform to risk-inform conclusions regarding compliance with the performance objectives. The comments relate to tank system performance modeling and include abstractions for corrosion of the steel liners, degradation of cementitious materials, and release of radionuclides from the tank system. These themes are consistent in NRC's Revision 0 and Revision 1 PA review comments.

NRC staff has evaluated DOE's responses to NRC's comments on the Revision 0 PA. Table NF-1 identifies whether the responses provided were adequate or inadequate. For some comments, NRC staff also determined that an inadequate response required follow-up via a RAI for more risk-significant information or a clarifying comment for information with lesser significance.

Based upon the review of the Revision 1 PA, NRC staff has also generated three new RAIs and several clarifying comments that may not be related to a previously raised issue listed in Table NF-1. The new RAIs are related to (i) lack of model support for the longevity of reducing conditions in the tank grout, (ii) inconsistencies in the equations used to calculate times to failure of the steel liner, and (iii) potential issues associated with experiments used to determine K_ds (may have been representative of solubility not sorption).

While many of NRC's comments on the Revision 0 PA were focused on simply understanding how DOE implemented its base case and probabilistic analysis and ensuring that results were complete and adequately presented to identify risk-significant features, events, and processes, NRC's new comments primarily focus on the adequacy of the technical basis for the base case conceptual model and supporting parameters for waste release. These comments include RAIs related to waste release conceptual models, model integration, steel liner failure times, selection of solubility limiting phase, solubility limits, chemical transition times, and K_ds of cementitious materials. Of particular concern, DOE notes on page 391 of the Revision 1 PA when justifying the fact that diffusion coefficients differed in the cementitious material degradation versus steel liner corrosion modeling that while submodel parameters may be inconsistent, the focus was on ensuring that each independent submodel is technically defensible. NRC staff does not agree that an integrated PA is necessarily technically defensible if its individual subcomponents are technically defensible or that each of DOE's submodels is sufficiently supported. For example, what might seem "conservative" for an individual sub-model may not be conservative when combined with other submodels to produce an integrated PA.

Another major technical issue repeated in several NRC comments is the potentially overly optimistic assumptions regarding steel liner performance in the base case scenario. DOE assumes a binary process with respect to the tank liners—the liner is either intact or it is failed. When the liner is intact, no fluid can flow into or out of the tanks. Thus, no waste releases out of the tank can occur. When the liner is failed, the steel tank no longer serves as a barrier to fluid flow. While early steel liner failures are non-mechanistically considered in DOE's uncertainty analysis as indicated in many of DOE's responses to NRC staff's comments on the Revision 0 PA, a number of potential features, events, and processes that may lead to faster corrosion rates were not considered in the *compliance* case. Furthermore, consideration of early, partial failure of the steel liner was not considered as part of DOE's compliance demonstration but may be important to the compliance demonstration given the fact that complete failure does not occur until beyond the compliance period for most F-Area tanks. It is significant to note that DOE's steel liner corrosion modeling predicts failure times beyond the 10,000 year compliance period for Type I and III/IIIA tanks, making it impossible for exceedances of the 10 CFR 61.41 performance objective to occur for these tanks. Thus, the steel liner serves as an important barrier to waste release in DOE's compliance demonstration.

It is important to note that many of NRC's comments reflect an underlying assumption--that aspects of Configurations A through F modeled in DOE's PA can and probably will occur in the real system and that no single Configuration or set of parameter values is likely to be representative of the actual dynamic system being modeled. For example, while iron co-precipitation may be the dominant mechanism controlling waste release for several key radionuclides in the tank system, DOE has not sufficiently characterized its waste to determine if more soluble phases of its key radionuclides also exist in the contaminated zone at risk-significant quantities following waste retrieval activities. While degradation of the cementitious materials and general corrosion of the steel liner may proceed as estimated in the base case analysis, DOE has not provided a defensible basis to support its assumption that preferential pathways for fluid flow into and out of the system will not lead to earlier, unconditioned release of key constituents from the waste zone, or that initial leak sites or pits that might develop or progress in the future will not lead to a smaller but risk-significant fraction of waste being released from the tank system earlier in the simulation period. NRC recommends that DOE evaluate these potential scenarios that may very well occur in the real system or justify why these scenarios should not be considered as part of the base case compliance demonstration.

To develop the following comments, staff reviewed the revised PA and supporting documents provided to NRC by letter dated April 2, 2010 (Gutmann, 2010). The staff's review criteria pertaining to near-field release of radionuclides are contained in Sections 4.2, 4.3.2, 4.3.3, 4.4, and 4.6 of NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007).

Table NF-1 Crosswalk of NRC Near-Field Comments Resulting from Review of the Revision 0 PA to the New RAI Comments Based on NRC's Review of the Revision 1 PA

Old #	Subject	Adequate	Inadequate (Not Repeated)	Follow-up Comment ID	Note
NF-1	Time-invariant cement material properties.			RAI-NF-6	A follow-up comment related to NF-1 was developed. The new comment is related to consideration of reinforcing steel in degradation modeling that could lead to changes in porosity and tortuosity that may lead to accelerated degradation or steel liner corrosion.
NF-2	Treatment of radioactive and non-radioactive components.	X			
NF-3	Use of expert judgment.			RAI-NF-10 RAI-NF-11 RAI-NF-14 CC-NF-8	Several follow-up comments generated on basis for parameter distributions related to chemical transition times, solubility controlling phases, bypass fraction, and cementitious material K_ds.
NF-4	Basemat spatial variability treatment.	X			
NF-5	Treatment of waterproofing membranes and plaster as part of basemat for Type I tanks.	X			
NF-6	Chemical transition Oxidized Region II to Oxidized Region III transition based on extrapolation.	X			
NF-7	Grout mineralogy impact on solubilities.	X			
NF-8	Pitting corrosion area equation			RAI-NF-2 RAI-NF-5	Follow-up comments related to lack of consideration of localized corrosion in the base case and basis for 25 percent area breached for pitting corrosion for auxiliary equipment.
NF-9	Pitting (vs. general) corrosion rates—basis and evaluation of uncertainty.			RAI-NF-2 RAI-NF-13 RAI-NF-16	New comment related to consideration of preferential pathways leading to accelerated steel corrosion and early waste release. New comment related to conceptual model for waste release considering bathtub effect and early release through leak sites or early pits.
NF-10	Time to steel depassivation from chloride attack.	X			
NF-11	Inconsistencies in cement and steel liner degradation conceptual models (diffusion vs. advection)			RAI-NF-3 RAI-NF-6 RAI-NF-13	Several new but related comments such as inconsistencies in the diffusion coefficients between submodels.
NF-12	Steel liner failure mechanisms—lack of consideration of galvanic, microbial, stress corrosion cracking, pitting and corrosion variability.			RAI-NF-2 RAI-NF-16	
NF-13	Steel liner corrosion rates for humid air.			RAI-NF-13	

NF-14	Steel liner failure due to stress corrosion cracking.			RAI-NF-16	Follow-up comment to consider the impact of partial failure of the steel liner via release from existing leak sites or leak sites that may form due to pitting.
NF-15	Thermodynamic data for solubility calculations.	X			
NF-16	pH end members for simulant calculations	X			
NF-17	Chemical conditions for K_d measurements.	X			
NF-18	Representativeness of 40-year concrete samples for oxidized concrete K_ds.			RAI-NF-12	
NF-19	Large variability in K_d values based on standard deviations—should not average values to come up with best-estimate K_d value.	X		CC-NF-6	While the response was adequate, a related clarifying comment was developed asking for a listing of all new sorption data reports.
NF-20	K_d of Tc under reducing conditions.			CC-NF-7	Follow-up comment on support for Bradbury and Sarrott K_d that may not be representative of FTF grout
NF-21	Support for tank dip samples from Tank 18 for solubility limits.	X			
NF-22	Support for iron co-precipitation model used for Tc and U solubilities.			RAI-NF-8	Follow-up comment related to consideration of more soluble phases not co-precipitated with iron.
NF-23	K_ds for Tc, U, and Pu and iron phases associated with iron co-precipitation model			RAI-NF-9	Follow-up comment related to potential for release during transitions from reducing to oxidizing.
NF-24	Conceptual model for chemical transitions—matrix versus fracture flow and lack of coupling between hydraulic and chemical properties.			RAI-NF-1 RAI-NF-10	In Section 5.6.3.8, variations are reported as significant for PA results. Related comments were developed related to depletion of reducing capacity along fractures and consideration of more rapid depletion along fractures when developing uncertainty ranges for chemical transitions.
NF-25	PORFLOW to GoldSim model abstractions—flow through waste tanks			RAI-NF-15 CC-NF-11 RAI-UA-5	See follow-up comments on roof impacts on flow through tanks. See follow-up comment on lack of consideration of Condition 2 flow through tanks (i.e., through preferential pathways and not through tank grout). See follow-up comment on lack of presentation of results for flow configurations E and F.
NF-26	Clarification of chemical transitions.			RAI-NF-15	See follow-up comment on Condition 2.
NF-27	Clarification of benchmarking adjustment to handle differences in the way solubilities are treated in GoldSim and PORFLOW.	X			
NF-28	Clarification of sensitivity analysis result that shows Region I K_ds are important when Region I K_ds are not used.	X			

RAI-NF-1

The technical basis in the PA should be enhanced for the assumed Eh values for Reducing Regions II and III and the estimated longevity of reducing conditions that is important to the retention of redox-sensitive radionuclides in the waste tanks.

Basis:

(i) In Section 4.2.2.1 of the PA and on page 5 of the cited reference WSRC-STI-2007-00544, Revision 1, (Denham, 2009) it was stated that for the reduced states, the system was equilibrated with the mineral pyrrhotite ($Fe_{1-x}S$) to account for the reducing capacity of the blast furnace slag in the grout. It was stated that pyrrhotite typically occurs at high temperatures and has been identified in various smelting slags. Denham (2009) also stated the grout Eh rapidly rises from 0.68 to −0.60 V, maintains this Eh for 39 pore volumes, then rapidly rises to −0.48 V and stays at this value for 371 pore volumes. At 371 pore volumes, the grout reducing capacity is exhausted and the Eh rises to about +0.55 V. The Eh evolution was stated to be due to mineral transformations and dissolution involving pyrrhotite and pyrite. Geochemical modeling indicated that pyrrhotite controlled the Eh during the first 40 pore volumes, and then pyrite buffered the Eh to −0.48 V through 371 pore volumes. When all pyrite was dissolved at 371 pore volumes, the Eh jumped to an oxidized value.

Experimental data is lacking to support the assumption that pyrrhotite and pyrite would buffer the Eh at low values in slag-bearing grout. Table NF-2 lists measured Eh values reported in the literature on fluids reacted with blast furnace slag and slag–cement mixtures. With the exception of the –553 mV Eh for the saltstone simulant, the measured values reported in the literature are higher than the Eh values derived based on assumed buffering by pyrrhotite and pyrite. Higher Eh values than those assumed in the PA could result in higher solubilities, lower K_ds, and higher releases of redox sensitive radioelements: technetium, plutonium, and neptunium.

(ii) Geochemical modeling described in Denham (2009), was used to calculate the number of pore volumes needed to transition from reducing to oxidizing chemical states. The modeling assumed all the reducing components in the grout (represented by pyrrhotite and pyrite) are available for reaction with the infiltrate. The calculated number of pore volumes, hence the longevity of reducing chemical state used in the PA, is likely overestimated. First, in actual field conditions, only a fraction of the reducing component will be accessible for reaction with the infiltrate particularly if flow occurs through fractures. Second, the amount of pyrrhotite used in Denham (2009), was based on the slag reducing capacity (0.82 meq/g) measured by Kaplan, et al. (2005). However, because the slag is nonporous, Kaplan, et al. (2005) measured the reduction capacity using finely ground samples to increase the reactive surface area. The reactive surface area and reducing capacity of reducing grout emplaced in the field are likely to be much smaller than that of laboratory samples. Thus, the longevity of reducing chemical states are likely to be shorter than assumed in the PA, which would affect the release rates of redox sensitive radioelements such as technetium, plutonium, and neptunium.

Path Forward:

Within the PA, provide additional information supporting the (i) assumed Eh buffering by pyrrhotite and pyrite and (ii) calculated longevity of reducing chemical states based on an assumed 100 percent reactivity of the reducing component in the grout. Alternatively, supporting calculations can be provide to demonstrate that the dose from redox sensitive radioelements will not be significantly affected by assuming (i) a higher Eh consistent with values reported in the literature and (ii) only a fraction of the reducing component in the grout will react with the infiltrate.

Reference

Denham, M.E., 2009. “Conceptual Model of Waste Release from the Contaminated Zone of Closed Radioactive Waste Tanks,” WSRC-STI-2007-00544, Revision 1. October 2009.

Kaplan, D.I., T. Hang, S.E. Aleman, 2005. “Estimated Duration of the Reduction Capacity Within a High-Level Waste Tank (U),” Westinghouse Savannah River Company LLC, Aiken, SC. 2005.

Table NF-2. Reported Redox Potential (Eh) of Fluids Reacted With Blast Furnace Slag and Slag-Bearing Cement-Based Material. For Comparison, Eh Values of Fluids Reacted With Ordinary Portland Cement and Saltstone Simulant Are Also Listed.

Reference	Measured Redox Potential (Eh, mV)*	Experimental Condition
Angus and Glasser (1985; Table V)†	+82 –315	OPC‡ BFS’ mixed with $Ca(OH)_2$ in the ratio 10:1
Angus and Glasser (1985; Table VI)†	+82 +79 +68 +35 –240 –269 –330 –259	100:0 OPC:BFS‖ 75:25 OPC:BFS 50:50 OPC:BFS 25:75 OPC:BFS 15:85 OPC:BFS 10:90 OPC:BFS 5:95 OPC:BFS& 2.5:97.5 OPC:BFS&
Angus and Glasser (1985; Table VIII)†	–227 –202	15:85 OPC:BFS‖; matured 25 days at 20 °C 15:85 OPC:BFS; matured 25 days at 40 °C
Gilliam, et al. (1988)#	+450 –250	OPC BFS
Atkins and Glasser (1992)**	0 to +100 –305±35††	100:0 OPC:BFS‖ 15:85 OPC:BFS
Kaplan and Hang (2007)‡‡	–247±1 (–50±1, corrected value)	BFS sample (the reported value was measured using a Ag/AgCl reference electrode;[##] assuming the reference electrode is KCl saturated, the reported value is adjusted by +197 mV to get the correct Eh)
Kaplan, et al. (2008)’’	–750 (–553, corrected value)	Saltstone simulant (the reported value was measured using a Ag/AgCl reference electrode;[##] assuming the reference electrode is KCl saturated, the reported value is adjusted by +197 mV to get the correct Eh)

*Versus standard hydrogen electrode
†Angus, M.J. and F.P. Glasser. “The Chemical Environment in Cement Matrices.” Scientific Basis for Nuclear Waste Management IX. Proceedings of the Materials Research Society Symposium Vol. 50. L.O. Werme, ed. Warrendale, Pennsylvania: Materials Research Society. 1985.
‡OPC—ordinary Portland cement
‘BFS—blast furnace slag
‖Mass ratio of OPC to BFS
&With 0.5 wt% NaOH solution added to ensure setting
#Gilliam, T.M., R.D. Spence, B.S. Evans-Brown, I.L. Morgan, J.L. Shoemaker, and W.D. Bostock. “Performance Testing of Blast Furnace Slag for Immobilization of Technetium in Grout.” Proceedings from Spectrum ‘88—International Topical Meeting on Nuclear and Hazardous Waste Management, Pasco, Washington, September 11–15, 1988. LaGrange, Illinois: American Nuclear Society. 1988.
**Atkins, M. and F.P. Glasser. “Application of Portland Cement-Based Materials to Radioactive Waste Immobilization.” *Waste Management.* Vol. 12. Pp. 105–131. 1992.
††Mean and standard deviation of six samples aged up to 10 months
‡‡Kaplan, D.I. and T. Hang. “Estimated Duration of the Subsurface Reduction Environment Produced by the Saltstone Disposal Facility on the Savannah River Site.” Rev. 0. WSRC–STI–2007–00046. Aiken, South Carolina: Westinghouse Savannah River Company. 2007
’’Kaplan, D.I., K. Roberts, J. Coates, M. Siegfried, and S. Serkiz. “Saltstone and Concrete Interactions With Radionuclides: Sorption (K_d), Desorption, and Reduction Capacity Measurements.” SRNS-STI-2008-00045. Aiken, South Carolina: Savannah River National Laboratory. 2008.
[##] Kaplan, D., personal communication, April 16, 2010.

RAI-NF-2

The analysis of steel liner failure times for the PA base case excluded localized corrosion as a degradation mechanism. No technical basis is provided why this degradation mechanism was excluded. Localized corrosion could lead to higher penetration rates and earlier failure of the steel liner.

Basis:

The DOE analysis assumed that carbon steel liner degradation under grouted condition primarily results from carbonation- or chloride-induced depassivation of the steel, which leads to accelerated corrosion (Subramanian, 2008). The liner failure time was calculated from the initiation time for carbonation- or chloride-induced corrosion plus the propagation time for corrosion through the liner wall. The steel liner degradation analysis for the base case, as reported in Table 4.2-35 of the PA, indicated that carbonation-induced depassivation time is much longer than chloride-induced depassivation time. As a consequence, chloride-induced corrosion was considered the controlling steel liner failure mechanism. In modeling chloride-induced corrosion, the DOE assumed that the oxygen needed to support the corrosion process is uniformly distributed as it diffuses through the concrete and is uniformly consumed by a general corrosion process along the entire liner surface. However, oxygen also can support localized corrosion processes, e.g. pitting, in which case the corrosion damage will be concentrated in a small area of the liner, result in a faster corrosion penetration rate, and cause earlier steel liner failure. Published literature shows that chloride-induced carbon steel depassivation often is accompanied by pitting corrosion (ASM International, 2003; Bertolini et al., 2004). However, pitting corrosion is neglected in the base case analysis, although both pitting and general corrosion are likely to proceed at the same time.

Path Forward:

Provide a technical basis for excluding localized corrosion as a degradation mechanism in the steel liner degradation analysis for the base case.

References

Subramanian, K.H., 2008. “Life Estimation of High Level Waste Tank Steel for F-Tank Farm Closure Performance Assessment, Rev. 2,” WSRC-STI-2007-00061, Rev. 2., Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. June 2008.

ASM International.ASM Handbook: Volume 13B: Corrosion: Materials. 2003.

Bertolini, L., B. Elsener, P. Pedeferri, and R. Polder, eds., 2004. “Corrosion of Steel in Concrete Prevention, Diagnosis, Repair,” Weinheim, Germany, Wiley-VCH Verlag GmbH & Co. 2004.

RAI-NF-3

Within the PA, justify the parameters and their values used in carbonation equations to support cementitious material degradation and steel liner corrosion for the base case and evaluate the realism or conservatism of concrete and steel liner failure times.

Basis:

The steel liner failure times in the FTF PA base case were derived from an analysis that compared the initiation times for carbonation-induced depassivation (Subramanian, 2008; page 23) versus chloride-induced depassivation (Subramanian, 2008; page 25) and applied the appropriate corrosion rate after initiation. The analysis assumed that (i) carbonation-induced depassivation and chloride-induced depassivation of the steel liner are diffusion-limited processes, (ii) carbon dioxide (in the case of carbonation) and oxygen (in the case of chloride-induced depassivation) has to diffuse through a minimum thickness of tank vault concrete, and (iii) the diffusion coefficient of carbon dioxide and oxygen are time invariant and equal to 1×10^{-6} cm^2/sec. The failure times reported for the base case are 12,747, 12,751, and 3,638 years for Types I, III/IIIA, and IV tanks, respectively (Table 4.2-35 of the PA).

On the other hand, the FTF PA base case abstraction of cementitious material degradation was based on an analysis that indicated carbonation would be the dominant degradation mode. The depth of penetration of the carbonation front was derived using a diffusion equation (SRNL, 2007; page 59, equation 15]. Concrete degradation initiation was calculated to occur as early as 1,300, 2,500, 2,400, and 400 years for Types I, III, IIIA, and IV tanks, respectively, and full degradation was calculated to occur in 2,600, 5,000, 4,800, and 800 years, respectively (Table 4.2-32 of the PA).

The two carbonation equations in Subramanian (2008) and SRNL (2007) are similar, but the parameter values are different. In addition, the concrete wall thickness for Type IV tank in Subramanian (2008) is 4 inches, whereas it is 7 inches in SRNL (2007). Confirmatory calculations were done using these two equations and the parameter values in Subramanian (2008) and SRNL (2007; page 60, Table 5-3). The results, which are summarized in Table NF-3, indicate that the two equations give completely different carbonation-induced concrete degradation and corrosion initiation times. The carbonation equation used in Subramanian (2008) results in a much longer carbonation-induced initiation time compared to the equation used in SRNL (2007). As a consequence, the steel tank liner corrosion modeling described in Subramanian (2008) indicated that the steel tank liner corrosion is mostly controlled by chloride induced corrosion, which results in much later tank liner failure time compared to that of the tank vault concrete.

It is important to note that the relative timing of failure of individual engineered barriers is risk-significant as it may dictate whether enhanced (i.e., no chemical buffering) waste release can occur earlier in the compliance period through preferential pathways or whether infiltrating water is conditioned during its migration through degraded concrete following steel liner failure. The timing of engineered barrier failure is also significant to the compliance demonstration as it also dictates whether failure and waste release occur prior to or following the compliance period (e.g., Type I and III/IIIA tank liners are assumed to fail after the 10,000 year compliance period).

Table NF-3. Calculated Concrete Lifetime Determined by Carbonation and Carbon Steel Tank Liner Corrosion Initiation by Carbonation and Chloride Diffusion

Tank Type	Concrete wall thickness[1] (in)	Concrete degradation initiation time determined by carbonation[2] (yr)	Carbon steel tank liner corrosion		
			Corrosion initiation time, years		Steel tank corrosion initiation mechanism[5]
			Carbonation[3]	Chloride diffusion[4]	
Type I	22	1,800	98,000	4,156	Chloride diffusion (Case 2)
Type III/IIIA	30	3,350	182,000	6,068	Chloride diffusion (Case 2)
Type IV	4	59.5	3,237	519	Chloride diffusion, then carbonation (Case 3)

[1]From Table 18 in SRNL (2008, p. 44, corrosion modeling)

[2]Calculated based on Equation 15 in SRNL (2007, p. 59, concrete degradation modeling). Concrete degradation was assumed to start once the carbonation effect reached one-half the concrete thickness.

[3]Calculated based on Equation in SRNL (2008, p. 23, corrosion modeling)

[4] Calculated based on Equation in SRNL (2008, p. 25, corrosion modeling)

[5]Determined based on three cases of potential corrosion in SRNL (2008, p. 50-58, corrosion modeling)

Path Forward:

Within the PA:

1. Provide the technical basis for using different carbonation equations and parameter values to model cementitious material degradation versus steel liner corrosion.

2. Evaluate the consequence of the inconsistency in the equations and parameter values on cementitious material degradation and carbon steel liner failure times for the base case analysis. As part of this evaluation, DOE should consider the impact of the assumed time invariant hydraulic properties (e.g., the diffusion coefficient for cement is expected to increase over time as the cement degrades).

Reference

SRNL, 2007. “Chemical Degradation Assessment of Cementitious Materials for the HLW Tank Closure Project,” WSRC-STI-2007-00607, Rev. 0., Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. September 2007.

Subramanian, K.H., 2008. “Life Estimation of High Level Waste Tank Steel for F-Tank Farm Closure Performance Assessment,” WSRC-STI-2007-00061, Rev. 2., Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. June 2008.

RAI-NF-4

The PA should reevaluate the carbon steel tank liner failure times for the base case using consistent equations and approaches for modeling liner failure.

Basis:

Two approaches—a deterministic method and a probabilistic method— were used to calculate carbon steel tank liner failure times for the PA base case (Subramanian, 2008). In the deterministic approach, the tank steel is assumed to corrode at an equivalent rate from both the interior and exterior surfaces (Subramanian, 2008; page 32). The time it takes to penetrate the tank wall (Subramanian, 2008; Figures 14 to 16, pages 32-34) was calculated using the equation

$$t_{failure}(yr) = t_{initiation}\,(yr) + \frac{Initial\ thickness\ (mils) - 0.04\left(\frac{mils}{yr}\right)t_{initiation}(yr)\times 2}{2\times(corrosion\ rate)(\frac{mils}{yr})} \quad \text{(Equation 1)}$$

In Equation 1, the passive corrosion rate was assumed to be 0.04 mils/yr, which was multiplied by 2 to calculate the overall corrosion rate and account for corrosion from both directions.

In the stochastic approach (Subramanian, 2008; Sections 5 and 6, pages 50-51 and 57-58), the following equation was used to calculate the liner failure time:

$$t_{failure}(yr) = t_{initiation}\,(yr) + \frac{Initial\ thickness\ (mils) - 0.04\left(\frac{mils}{yr}\right)t_{initiation}(yr)}{(corrosion\ rate)(\frac{mils}{yr})} \quad \text{(Equation 2)}$$

The corrosion rate used in Equation 2 was not multiplied by 2, which implies that corrosion was assumed to proceed from only one side of the tank wall, in contrast to the assumption used in the deterministic approach. Table NF-4 compares the tank liner failure times calculated using Equations 1 and 2 and other relevant equations and median parameter values presented in Subramanian (2008), pages 46-48 and 50, to those in Table 4.2-35 of the PA document. Confirmatory calculation results from Equation 2 are consistent with what reported in Table 4.2-35 of the PA document. However for Types I and III/IIIA tanks under A, B, F configurations, the failure times calculated from Equation 1 are about half of those calculated from Equation 2. Confirmatory calculations (not shown here) also found that for these cases including the base case in the PA the carbon steel liner corrosion is initiated by chloride depassivation and the corrosion propagation rate is controlled by oxygen diffusion. The shorter failure times calculated from Equation 1 suggests that the carbon steel liner could fail earlier than that reported in Table 4.2-35 of the PA document.

Path Forward:

Within the PA:

1. Provide a technical basis for assuming that corrosion propagates from only one side of the tank wall.

2. Evaluate tank failure times using consistent equations and parameters.

Reference

Subramanian, K.H., 2008. "Life Estimation of High Level Waste Tank Steel for F-Tank Farm Closure Performance Assessment," WSRC-STI-2007-00061, Rev. 2., Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. June 2008.

Table NF-4. Comparison of Carbon Steel Tank Failure Times from Table 4.2-35 of WSRC-STI-2007-00061 and Confirmatory Calculations Using Median Parameter Values

Table 4.2-35 in PA document				Confirmatory calculation	
Tank Type	Applicable conditions	Condition	Failure time (yr)	Failure time from Equation 1 (yr)	Failure time from Equation 2 (yr)
Type I	A, B, F	Grouted liner, diffusion coefficient 1E-6	12,747	6,375	12,750
	C, D, E	Grouted liner, diffusion coefficient 1E-4	1,140	1,001	1,026
Type III/IIIA	A, B, F	Grouted liner, diffusion coefficient 1E-6	12,751	6,375	12,750
	C, D, E	Grouted liner, diffusion coefficient 1E-4	2,077	1,839	1,865
Type IV	A, B, F	Grouted liner, diffusion coefficient 1E-6	3,638	3,244	3,263
	C, D, E	Grouted liner, diffusion coefficient 1E-4	75	51	71

RAI-NF-5

Within the PA, justify the basis for using a 25% pitting penetration percentage as the failure criterion for the ancillary equipment especially the stainless steel transfer lines.

Basis:

In the PA probabilistic analysis and its supporting document (Subramanian, 2007), the most probable time of ancillary equipment failure was calculated to be 510 years based on an assumed 25% pitting penetration as the failure criterion. However, no technical basis is provided to justify 25% pitting penetration, rather than a lower value, as a reasonable failure criterion for the ancillary equipment, especially for the stainless steel transfer lines. Timing of ancillary equipment failure could be risk-significant for relatively short-lived radionuclides that at longer timeframes will decay to negligible levels prior to release.

Path Forward:

Provide the basis for the 25% failure criterion for the ancillary equipment in the context of the overall performance assessment.

Reference

Subramanian, 2007. "Life Estimation of Transfer Lines for Tank Farm Closure Performance Assessment," WSRC-STI-2007-00460, Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. October, 2007.

RAI-NF-6

Provide a technical basis for excluding the effects of reinforcing and pre-stressing steel on cementitious material degradation and steel liner corrosion.

Basis:

The PA states, on page 180, that the impact of carbonation, expected to be the most extensive attack mechanism on cementitious materials, is dependent upon the presence of steel and that Type IV tanks do not contain rebar or steel, thus the overall effect of carbonation should be minimal regardless of the depth of penetration. This assertion that steel is not present in the wall of Type IV tanks appears to be contradicted in the PA on page 140 and by DP-478.

Additionally, consideration of the effects of steel reinforcement on cementitious material degradation and steel liner corrosion was excluded for Type I and Type III/IIIA tanks due to the planned grouting of the annular regions which would not contain reinforcing steel (PA, page 180). However, the steel liner corrosion analysis in WSRC-STI-2007-00061 (page 24) used a thickness of 22-inches for the Type I tanks which corresponds to the minimum thickness of the concrete vault dimension and presumably is based on the tank roof containing reinforcing steel.

Corrosion of the reinforcement steel in the various tank types, particularly Type IV, is likely to alter the properties (e.g., porosity, tortuosity) of the concrete walls with time, potentially resulting in cracking or spalling of the walls and leading potentially to fast pathways and increased degradation rates of the cementitious material and steel liner compared to those estimated in the base case.

Path Forward:

Provide an adequate technical basis to exclude the effects of reinforcing steel on cementitious material degradation and steel liner corrosion in the various tank types.

References

Daniel, A.N., 1960. “Underground Storage of Low-Level Radioactive Wastes at the Savannah River Site (Engineering Considerations),” DP-478, Issued by E.I. du Pont de Nemours & Co. Explosives Department—Atomic Energy Division, Wilmington, Delaware. June 1960.

Subramanian, K.H., 2008. “Life Estimation of High Level Waste Tank Steel for F-Tank Farm Closure Performance Assessment,” WSRC-STI-2007-00061, Rev. 2., Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. June 2008.

RAI-NF-7

Provided stronger technical bases for K_d values of 10,000 and 1,000 mL/g for transport of plutonium through Middle Age and Old Age cementitious materials, respectively. K_d values for neptunium may also be affected by solubility.

Basis:

A K_d of 10,000 mL/g is established in Table 4.2-33 for transport of Pu through grout and the concrete basemat for Middle Age cementitious materials, and a value of 1,000 mL/g applies to Old Age material. Most importantly, these values provide significant retardation of plutonium in the basemat under oxidizing conditions, particularly for Middle Age concrete. The original references for the K_d values (WSRC-STI-2007-00640 and SRNS-STI-2008-00045) are the same as were used to support the corresponding parameters in the Saltstone PA. A comment during NRC staff review of the Saltstone PA raised the question of whether the Pu K_d measurements on cementitious materials could have reflected solubility, rather than sorption, potentially leading to overestimation of the sorption coefficient (SP-10, quoted in SRR-CWDA-2010-00033, Revision 1, July 2010). The observations of plutonium solubility control arose in an SRNL sorption study (SRNL-STI-2009-00636). The DOE response to the NRC comment did not resolve the question, but instead argued for the relatively low risk significance of the Pu K_d values (Response SP-10 in SRR-CWDA-2010-00033, Revision 1, July 2010). This argument does not necessarily apply to the F Tank Farm PA, particularly with respect to transport through the basemat. DOE needs to address the question of whether solubility effects in supporting experiments could lead to overestimation of Pu retardation in cementitious materials in the F-Tank Farm PA.

The question of possible solubility effects on Pu sorption measurements may also apply to Np (SRNL-STI-2009-00636; SP-10 and Response SP-10 in SRR-CWDA-2010-00033, Revision 1, July 2010).

Path Forward:

The technical basis for the Pu K_d values for reducing and oxidizing Middle Age, and oxidizing Old Age, cementitious materials should be re-addressed with respect to whether laboratory measurements could have significantly overestimated the sorption coefficients due to solubility effects.

The technical bases for Np K_d values for cementitious materials in Table 4.2-33 should also be re-addressed with respect to whether laboratory measurements could have significantly overestimated the sorption coefficient due to solubility effects.

References

Kaplan, D.I., and J.M. Coates, 2007. "Partitioning of Dissolved Radionuclides to Concrete Under Scenarios Appropriate for Tank Closure Performance Assessment," WSRC-STI-2007-00640, Savannah River National Laboratory, Washington Savannah River Company, Savannah River Site, Aiken, SC. December 2007.

Kaplan, D.I., K. Roberts, J. Coates, M. Siegfried, and S. Serkiz, 2008. "Saltstone and Concrete Interactions With Radionuclides: Sorption (K_d), Desorption, and Reduction Capacity Measurements." SRNS-STI-2008-00045, Savannah River National Laboratory, Aiken, SC. 2008.

SRR, 2010. "Comment Response Matrix for Nuclear Regulatory Commission (NRC) Requests for Additional Information (RAIs) on the Saltstone Disposal Facility Performance Assessment," SRR-CWDA-2010-00033, Revision 1, Savannah River Remediation, Closure & Waste Disposal Authority, Aiken, SC. July, 2010.

Lilley, M.S., B.A. Powell, D.I. Kaplan. 2009. "Iodine, Neptunium, Plutonium, and Technetium Sorption to Saltstone and Cement Formulations Under Oxidizing and Reducing Conditions," SRNL-STI-2009-00636, Savannah River National Laboratory, Aiken, SC. December 19, 2009.

RAI-NF-8

Additional confidence is needed to provide reasonable expectation that co-precipitation with iron phases will constrain Pu and Tc to such low dissolved concentrations under oxidizing conditions. Consideration should also be given to modeling a certain percentage of Tc existing in a more soluble form.

Basis:

The revised PA (Section 4.2.2.4) and the revised supporting report Denham (2010; WSRC-STI-2007-00544, Rev. 2) provide more extensive discussions in support of the iron co-precipitation model for constraining dissolved concentrations of some elements under Region II conditions. For the risk significant element Pu, this model predicts a concentration nine orders of magnitude lower under Region II oxidizing conditions than under Region III oxidizing conditions. For the risk significant element Tc, the model predicts a very low concentration of 3×10^{-13} M under Region II oxidizing conditions, contrasted with no concentration limit under Region III oxidizing conditions. These marked differences, which lead to very low predicted release rates for these elements until Region III is approached, call for strong technical bases.

The co-precipitation model relies on the assumption that all Pu or Tc remaining in tank residue, assumed to be thoroughly cleaned, is in a relatively insoluble form—specifically, co-precipitated in magnetite or hematite. The reports cited appear to support the general observation. However, if only a very small fraction of the element remained in the tank residue in some form other than iron oxide co-precipitate, either in the pore fluid or in other solid phases, the predicted concentrations could be in error by a large amount. It is not apparent that sufficient empirical observations have been made that support the particular concentration limits adopted in the PA for Region II. This is particularly true for oxidizing conditions, under which both Pu and Tc are expected to be significantly more mobile than under reducing conditions.

Further, PNNL-17593 reported significant fractions (~17%) of Tc released very quickly (on the order of months) during extraction experiments. Based on SRS PA Rev 1 results, it appears that only a small soluble fraction (possibly as low as 5%) would likely lead to an exceedance of the performance objectives. It is not apparent that sufficient observations have been made to demonstrate that there is an insignificant soluble fraction of Tc remaining in the tanks, particularly for tanks in which the use of oxalic acid is or was not possible.

Path Forward:

Provide additional technical support for the specific concentration limits adopted for Region II for Pu and Tc, with emphasis on oxidizing conditions, and considering the potential for relatively small masses of the elements not sequestered in iron oxides to affect the predicted values. DOE could consider modeling a separate fraction of more soluble Tc not assumed to be co-precipitated with iron.

Reference

Krupka, K.M., et al., 2004. “Hanford Tanks 241-AY-102 and 241-BX-101: Sludge Composition and Contaminant Release Data,” PNNL-17593, PNNL, Richland, Washington. May, 2004.

RAI-NF-9

Provide information to clarify whether the iron oxide co-precipitation model considers the effects on element mobility of the redox transition of the iron phases.

Basis:

The iron oxide co-precipitation model for constraining Pu, Tc, and U concentrations in Region II assumes that magnetite sequesters these elements under reducing conditions, and hematite is the host phase under oxidizing conditions. The model is based on observations of association of these elements with iron phases in tank residues. Implicit in the conceptual model is a transition from magnetite to hematite as the system evolves from initially reducing to later oxidizing. It should be considered that, during this transition, sequestered Pu, Tc, and U could be released to pore water or to other solid phases as the iron oxides are dissolved and precipitated, or otherwise modified. It is possible, therefore, that those elements may not be co-precipitated with hematite under oxidizing conditions and that subsequent release could be controlled by other processes.

Path Forward:

Consider the fate of Pu, Tc, and U as iron oxides transition from reducing to oxidizing conditions and address the implications for element concentrations predicted by the iron co-precipitation model under oxidizing Region II conditions.

RAI-NF-10

Provide a technical basis for the adequacy of the uncertainty in chemical state transition times.

Basis:

Section 5.6.3.8 of the FTF PA Rev. 1 indicates that the transition times for chemical states are based on the estimated number of pore volumes passing through the grout. The range of uncertainty in these transition times were chosen as ±30% for the first transition time and ±50% for the second transition time. These selections were based on professional judgment. However, the documentation provides neither a transparent nor traceable basis for which factors influenced the selections. Uncertainty ranges in the transition times could be estimated through modeling that appropriately propagates uncertainties in input parameters to the modeling supporting the estimation of the base case values with appropriate treatment of conceptual model uncertainty (e.g., the existence of fast flow paths with less reactive fractions – see RAI-NF-1). These chemical state transition times have a significant impact on radionuclide solubility and thus mobility from the contaminated zone as reported in the uncertainty, sensitivity, and barrier analyses - Sections 5.6.4.2.1, 5.6.4.2.2, 5.6.6.3, 5.6.7.3.4.4, and 5.6.7.3.4.5. This RAI is closely related to RAI-NF-1.

Path Forward:

Provide a transparent and traceable technical basis for the estimation of chemical state transition time uncertainty.

RAI-NF-11

Provide a transparent and traceable technical basis for the adequacy of the likelihood of solubility controlling phases

Basis:

Section 4.2.2.3.1 of the FTF PA Rev 1 indicates the likelihoods of the solubility controlling phases were selected based on observations in the literature, thermodynamic stability, etc. Sections 5.6.4.2.1, 5.6.4.2.2, and 5.6.6.3 of the FTF PA indicate that the solubility-limiting phase is significant to the release of key radionuclides from the contaminated zone. Given the significance of these professional judgments, a transparent and traceable description of the selection of the likelihood estimates from the observations in literature, thermodynamic stability, etc. should be provided for each of the key radionuclides. Alternatively, laboratory simulations of expected conditions for each of the abstracted chemical states could be conducted to understand the uncertainty in the likelihood of the solubility limiting phases.

Path Forward:

Provide a transparent and traceable description of the selection of the likelihood estimates for solubility controlling phases for key radionuclides.

RAI-NF-12

Provide a discussion of the rationale for the applicability of data using 40 year-old concrete in predicting very long-term sorption behavior of basemat concrete. The response to original NF-18 (SRR-CWDA-2009-00054, Rev 0, March 2010, pp 66-67) did not provide such a discussion.

Basis:

The response to original NF-18 (SRR-CWDA-2009-00054, Rev 0, March 2010, pp 66-67) clarified the bases for some of the cementitious materials K_d choices made as a result of SRS experimental studies. The response did not, however, address the request to provide a discussion of the rationale for the applicability of data using 40 year-old concrete in predicting very long-term sorption behavior of basemat concrete. As discussed in the original NF-18, the solid phases making up the sampled concrete used in the Kaplan, et al. (2007) sorption experiments will not necessarily correspond to the constituents of much older concrete present in the basemat if radionuclides are released thousands of years after tank closure.

Path Forward:

The PA should provide the technical basis for using 40 year-old concrete (Kaplan et al., 2007) as a surrogate for the sorption behavior of aged basemat concrete throughout the modeled time period in the tank farm performance assessment.

Reference

SRR, 2010. "Comment Response Matrix for Nuclear Regulatory Commission (NRC) Comments on the F-Tank Farm Performance Assessment," Savannah River Remediation (SRR) Closure & Waste Disposal Authority, Aiken, SC. March 2010.

Kaplan, D.I., et al., 2007. "Concrete K_d Values Appropriate for the Tank Closure Performance Assessment," WSRC-RP-2007-01122, Savannah River Site, Aiken, SC, 2007.

RAI-NF-13

Provide a basis for lack of consideration of known preferential pathways for water ingress into Type I, Type III/IIIA, and Type IV tanks and the potential for ongoing fluid flow along or in contact with the steel liners that could lead to enhanced corrosion rates and early waste release from the tanks in the base case scenario.

Basis:

DOE's corrosion modeling indicates that steel in the presence of soil or humid air could lead to significantly reduced corrosion times (WSRC-STI-2007-00061, Rev. 2). Groundwater infiltrating through preferential pathways into the tank system is less likely to be conditioned relative to water that migrates through a concrete matrix. Therefore, groundwater in-leakage through preferential pathways could lead to enhanced steel liner corrosion rates compared to the current base case. In-leakage has been documented for Type I tanks (WSRC-STI-2009-00352); Type III/IIIA tanks (WSRC-STI-2009-00352; SRR-STI-2010-00283); and Type IV tanks (DPSPU-82-11-10; WSRC-STI-2009-00352; SRR-STI-2010-00283; DOE/SRS-WD-2010-001;

SRNS-STI-2008-00096). While the annular regions for the Type I and Type III/IIIA tanks will be grouted during closure, the historical performance of the cementitious materials indicates that a potential for future in-leakage will, nonetheless, exist. Type IV tanks do not have an annular region that can be grouted during closure. Therefore, pathways for fluid flow between the steel liner and tank wall that currently exist are expected to continue to exist following tank closure and likely to increase as pre-stressing bands (i.e., tendons) corrode and relieve the compressive stresses in the tank walls. Transfer line piping that enters the tank wall and tank system components that are not able to be grouted during closure may also corrode prior to steel liner failure or otherwise present potential conduits for fluid flow into the vaults or tanks. Considering the unsaturated conditions that may form (or that currently exist) in gaps between the liner and tank grout; the liner and the vault grout or vault; or the steel liner and basemat, corrosion rates consistent with steel in contact with soil or humid air as documented in WSRC-STI-2007-00061, Rev. 2 may be more appropriate than assuming corrosion rates consistent with steel liner in contact with cement.

Additionally, Type IV tanks are located near the water table and the bottom of Type IV tanks (e.g., Tanks 19 and 20) are expected to be located within the zone of water table fluctuation; therefore, there is an additional mechanism that should specifically be evaluated for Type IV tanks in the *base case* configuration. Groundwater in-leakage into the known imperfect seal between the basemat and steel liner has occurred in the past. Cyclic wetting and drying of the Type IV tank bottoms may lead to significantly more aggressive service conditions than considered in the base case cement degradation and steel liner corrosion modeling. In fact, DOE-EIS-0303 documents the presence of cracks in Tanks 19 and 20 thought to be attributable to corrosion of the tank wall from occasional groundwater inundation from the fluctuation in the water table above the tank bottoms (2002).

Type IV tanks that have no liner top are predicted by DOE modeling to experience a bathtub effect that may lead to the accumulation of unconditioned water in the steel tanks prior to significant tank grout degradation. The potential also exists for groundwater inleakage into the steel tanks and accumulation of groundwater as currently experienced by FTF tanks. Pitting corrosion is known to be more severe under dilute conditions in SRS tanks near the liquid/air interface. It is not clear how water accumulation in the tanks might affect corrosion.

Early tank vault degradation could also lead to enhanced transport rates of corrosive agents into the tank vault but an increase in the diffusion coefficient over time is not considered as part of DOE’s base case corrosion modeling. This comment applies to all tank types as DOE assumes a time invariant diffusion coefficient of 1E-06 cm^2/s in its base case corrosion modeling that is not expected to be reflective of degraded cement conditions. For example, diffusion of oxygen through unsaturated cracks could lead to an increased potential for localized corrosion. It is significant to note that the deterministic analysis in WSRC-STI-2007-00061, Rev. 2 assumes a diffusion coefficient of 1E-04 cm^2/s and the comprehensive stochastic modeling also considers an effectively higher diffusion coefficient than the partial stochastic methodology parameter distribution ultimately selected for DOE’s compliance case reflective of relatively intact concrete. Thus, the compliance case steel liner failure times in the PA are prolonged compared to what they would have been if either (i) the deterministic or (ii) fully stochastic methodology approaches presented in the supporting technical reference (WSRC-STI-2007-00061, Revision 1) had been selected.

Results of the uncertainty analysis clearly show the importance of the steel liner failure times with respect to potential peak dose (see for example Figures 5.6-58 and 5.6-60 that indicate doses approaching tens of thousands of mrem/yr or a hundred mSv/yr within a 20,000 year simulation period and Figure 5.6-61 results that show doses in excess of 50 mrem/yr (0.5 mSv/yr) within a 10,000 year compliance period with peak doses clearly correlated to steel liner failure time for Configuration D [configuration with by-passing pathways]).

Path Forward:

Perform additional calculations (or use currently available results for alternative failure mechanisms evaluated in WSRC-STI-2007-00061, Revision 2) to evaluate potential mechanisms for early steel liner failure discussed in this comment in the base case scenario including the following:

1. Preferential pathways for unconditioned groundwater or air to contact the steel liner or degradation of transfer line piping or other tank system components leading to the creation of open conduits for fluid flow into the tanks/vaults (i.e., the system may be better represented by a steel liner in contact with soil or humid air).

2. Wet and dry cycling of the bottom of Type IV tank bottoms.

3. Potential accumulation of groundwater in all tank types.

4. Time variant diffusion coefficients that increase over time due to cement degradation including consideration of gas phase transport of oxygen through cement vault cracks.

Alternatively, DOE could indicate why these conditions are unlikely to exist or lead to accelerated corrosion of the steel liners. Due to the high risk-significance of the steel liner barrier to the compliance demonstration, NRC also recommends DOE consider any potential closure design features that might be employed to mitigate the risk of enhanced corrosion of its steel liners to prevent early waste release from the grouted tank system.

References

Subramanian, K.H., 2008. “Life Estimation of High Level Waste Tank Steel for F-Tank Farm Closure Performance Assessment, Rev. 2,” WSRC-STI-2007-00061, Rev. 2., Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. June 2008.

Waltz, R.S., and W.R. West, 2009. “Annual Radioactive Waste Tank Inspection Program – 2008.” WSRC-STI-2009-00352, Washington Savannah River Company, Aiken, SC. June 2009.

Waltz, R.S., and W.R. West, 2009, 2010. “Annual Radioactive Waste Tank Inspection Program-2009,” SRR-STI-2010-00283, Savannah River Remediation, Savannah River Site, Aiken, SC. June 2010.

McNatt, F.G., 1982. “History of Waste Tank 20 1959 Through 1974.” DPSPU-82-11-10, E.I. du Pont de Nemours & Company, Savannah River Plant. July 1982.

DOE, 2010. “Draft Basis for Section 3116 Determination for Closure of F-Tank Farm at the Savannah River Site,” DOE/SRS-WD-2010-001, Revision 0, US DOE. September, 2010.

B.J. Wiersma, 2008. “An Assessment of the Service History and Corrosion Suspectibility of Type IV Waste Tanks.” SRNS-STI-2008-00096. Savannah River National Laboratory, Materials Science and Technology Directorate. September 2008.

DOE, 2002. “High-Level Waste Tank Closure, Final Environmental Impact Statement,” DOE-EIS-0303. May, 2002.

RAI-NF-14

Provide a basis for the likelihood of basemat bypass.

Basis:

In response to comment NF-3, information regarding the basis for the selection of the range of uncertainty in the likelihood of basemat bypass was not included in the FTF PA Revision 1. Furthermore, it is not clear why basemat bypass in not considered in the base case given the presence of known pathways for fluid flow between the basemat and steel liner for at least Type IV tanks (see comment RAI-NF-13 above) and given the presence of air channels or leak collection channels in Type III/IIIA and Type IV tanks.

Path Forward:

Justify lack of consideration or evaluate basemat bypass as part of the base case scenario.

RAI-NF-15

Justify lack of consideration of a Condition 2 waste release scenario (as characterized on page 263 of the revised PA) in the PA analyses.

Basis:

In the Revision 0, PA, DOE attempted to implement a Condition 2 waste release scenario (see Figure 4.2-1 in the Revision 1 PA) as requested by NRC staff in FTF scoping[3]. Condition 2 is a waste release scenario where preferential pathways exist through the tank system (e.g., due to the imperfect seal that forms between tank components (e.g., steel liner, piping, and cooling coils) and grout used to fill the void systems in the tank system during closure) prior to significant grout degradation such that the infiltrating water is not conditioned during its travel path through the contaminated zone. Considering the fact that there are current known pathways for fluid flow through the Type I, III/IIIA, and IV tank systems that may facilitate by-passing of infiltrating water through the tank prior to significant degradation of the tank grout (see comment NF-13), this scenario may be more likely than originally thought. In the Revision 1 PA, DOE opted to change the implementation of the preferential pathway case

[3] The word “attempted” is used here as NRC questioned the actual execution of the fast flow case (otherwise known as Condition 2 or Configuration D) in the Revision 0 PA (see comment NF-25, NF-26, and UA-4) due to numerous ambiguities that existed between the tables and text.

embodied in Configuration D into a scenario that is not consistent with Condition 2. Instead, the preferential pathway case is implemented in a scenario where the grout is significantly degraded upon steel liner failure, such that infiltrating water undergoes advective transport through the reducing tank grout and thereby conditions the infiltrating water such that chemical transitions leading to higher solubilities are prolonged (see Tables 4.4.-2 through 4.4-5 showing the process change timeline for the various tank types in the Revision 1 PA) and the potentially large impact of preferential or by-passing pathways through the system is muted. This scenario emphasizes the importance of (i) the relative timing of steel liner failure versus cementitious material degradation and (ii) the definition of "failure[4]" as it pertains to the steel liner (e.g., earlier failures due to presence of existing leak sites or due to pitting corrosion and prior to significant degradation of the tank grout may become important).

Implementation of a preferential pathway configuration is risk-significant as it leads to a situation where groundwater intruding into the tank system is unconditioned (does not interact with the reducing grout or the buffering capacity of the intruding groundwater is rapidly depleted along the preferential pathway) facilitating the release of radionuclides from the system at risk-significant rates. DOE's barrier analysis illustrates the importance of the Condition 2 scenario—see for example Case 11 that most closely resembles a Condition 2 scenario with a fast pathway existing through mostly intact grout. Case 11 represents one of the most catastrophic failure configurations analyzed in the barrier analysis for several tank and radionuclide combinations. Thus, the rationale for the change in the implementation of Configuration D, which is inherently, a by-passing pathway configuration, should be clearly communicated and appropriately justified.

Path Forward:

Owing to its risk-significance and potential likelihood, NRC recommends that DOE evaluate the consequences of a Condition 2 waste release scenario or otherwise indicate why this scenario is not expected to occur considering the factors listed above. Sensitivity analysis with regard to the timing and amount of unconditioned groundwater that might contact the contaminated zone and/or by-pass the basemat earlier in the compliance period prior to complete grout degradation could be conducted and used to enhance the robustness of the compliance case. DOE should bear in mind that early waste release through preferential pathways may occur earlier in the simulation period, while the bulk of radioactivity may be released later in the compliance period as predicted by the base case scenario (i.e., DOE should consider that its base case and alternative configurations are not mutually exclusive). As appropriate, and consistent with removal to the maximum extent practical or ALARA criteria, DOE should consider mitigative measures that may be taken to reduce the likelihood, or mitigate the consequences of this potentially high-consequence event.

DOE should also demonstrate that sufficient flow occurs through the grout for Type IV tanks upon steel liner failure to condition the incoming water at early times (Type IV tanks undergo relatively early steel liner failure but relatively late cementitious material degradation as these

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[4] The term "failure" is used here to suggest that failure could mean any situation where waste could be released from the tank system in significant quantities (e.g., the entire thickness of the steel liner does not need to be corroded via general corrosion or 100 percent of the steel liner area does not need to be breached due to pitting corrosion to constitute failure of the barrier in mitigating the release of radionuclides from the tank system).

tanks do not contain any cooling coils). For example, DOE could provide information regarding the relative flow rates of infiltrating water through the matrix versus through simulated fractures (with expected faster chemical transitions through fractures) following steel liner failure.

RAI-NF-16

DOE should evaluate the impact of early release (e.g., from existing leak sites or leak sites that may form prior to depletion of the entire thickness of the steel liner due to general corrosion) or justify why this mechanism for waste release should not be evaluated in the PA.

Basis:

Considering DOE's continued reliance on the steel liner for Type I and III/IIIA tanks as an effective barrier to waste release until times significantly beyond the 10,000 year compliance period, DOE should specifically evaluate the impact of early releases from all tank systems from existing leak sites as well as from early pits that may form prior to complete steel liner consumption from general corrosion (see comment RAI-NF-13). Early steel liner failure could lead to groundwater contacting the waste zone, a bathtub effect, and early release of constituents into the environment through a leak site located at the bathtub level or releases could occur through leak sites that form at or near the bottom of the tanks. This scenario may be more likely for Type IV tanks that have no liner top and already experience a bath-tub effect in DOE's base case scenario. Type IV Tank 19 also contains leak sites near the top and bottom of the tanks (SRR-STI-2010-00283) that may serve as pathways for radionuclide release. Type IV Tanks 19 and 20 contain cracks believed to be a result of occasional groundwater inundation from fluctuations in the water table (DOE-EIS-0303, 2002). Type I tanks also contain a number of known leak sites (e.g., Tanks 1, 5 and 6).

As indicated in WSRC-STI-2007-00061, Rev. 2, the progressive breaching of the tank steel is likely the most representative of the natural phenomena of corrosion of the steel. The DOE report indicates that information provided as part of the comprehensive stochastic methodology could be used as input for modeling the outflow of contaminants from the tanks by using a figure of merit for percentage breached for a "patch" type model which will progressively fail the tank and assume that past a critical percentage breached, the tank no longer acts as a barrier to waste releases. While potentially challenging to implement, this approach seems comparable with other technical complexities in the PA modeling that should be considered and may represent a more realistic and technically defensible approach for the compliance case.

Early release is risk-significant for relatively short-lived radionuclides or radionuclides whose risk impact is very large but at longer simulation periods beyond the period of performance (e.g., Pu and Tc releases that over longer simulation timeframes approach hundreds to thousands of mrem/yr or up to tens of mSv/yr) as even a small fraction of the potential peak dose (e.g., one to few percent in the base case and less than one percent for the fast flow case, Configuration D) for certain key radionuclides is similar to the 25 mrem/yr (0.25 mSv/yr) dose criterion and a greater number of radionuclides would contribute to the peak dose earlier in the simulation time period.

Path Forward:

Evaluate the potential impact of early waste release from the tank system due to existing leak sites or leak sites that may form (or progress) in the future or justify lack of consideration of this scenario in its PA (i.e., base case and alternative configurations).

References

Waltz, R.S., and W.R. West, 2010. "Annual Radioactive Waste Tank Inspection Program-2009," SRR-STI-2010-00283, Savannah River Remediation, Savannah River Site, Aiken, SC. June 2010.

DOE, 2002. "High-Level Waste Tank Closure, Final Environmental Impact Statement," DOE-EIS-0303. May 2002.

Subramanian, K.H., 2008. "Life Estimation of High Level Waste Tank Steel for F-Tank Farm Closure Performance Assessment, Rev. 2," WSRC-STI-2007-00061, Rev. 2., Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. June 2008.

Clarifying Near-Field Comments

CC-NF-1

Verify the 967 g/m^3 of pyrrhotite listed in Table 4.2-20 in Section 4.2.2.6 of the PA. The basis for this value is discussed in WSRC-STI-2007-00544, Revision 1. On page 34 of WSRC-STI-2007-00544, Revision 1, it is stated that there are 91 meq/g FeS and 0.82 meq/g slag. Therefore,

$$\frac{0.82\ meq}{g\ slag} \div \frac{91\ meq}{g\ FeS} = \frac{0.00901\ g\ FeS}{g\ slag} = 0.901\ wt\%\ FeS\ in\ slag$$

The value of 0.901 wt% FeS in slag is different from the value of 0.84 wt% FeS listed in Table 17 (Column 4) of WSRC-STI-2007-00544, Revision 1. Table 16 of WSRC-STI-2007-00544, Revision 1 also stated there are 210 lb of slag per cubic yd of reducing grout, or 124,588 g of slag per cubic meter of grout. Therefore,

$$\frac{124{,}588\ g\ slag}{m^3\ grout} \times \frac{0.00901\ g\ Fes}{g\ slag} = \frac{1{,}123\ g\ FeS}{m^3\ grout}$$

The calculated value of 1,123 g FeS/m^3 grout is 16 percent higher than the value of 967 g FeS/m^3 grout listed in the WSRC-STI-2007-00544, Revision 1 and in Table 4.2-20 in Section 4.2.2.6 of the PA. The higher value would increase the time duration of reducing condition.

Reference

Denham, M.E., "Conceptual Model of Waste Release from the Contaminated Zone of Closed Radioactive Waste Tanks," WSRC-STI-2007-00544, Revision 1, October 2009.

CC-NF-2

Section 4.2.3.2.3 of the PA indicates that the transition from Reduced Region III to Oxidized Region III occurs at 20,000 years for the Base Case. However, the PORFLOW model files indicate that this transition occurs at 26,868 years. Provide (i) clarification on the transition time from Reduced Region III to Oxidized Region III and (ii) a technical basis for this transition occurring at 26,868 years.

CC-NF-3

Section 5.6.2.1.2 of the PA discusses the use of solubility controls to model contaminant release within PORFLOW. However, the PORFLOW model files indicate that a K_d approach was utilized to model contaminant release. It appears that an attempt was made to implement solubility control in the model through use of a K_d specified for three different time periods corresponding to (i) initial conditions, (ii) time period after the first chemical transition, and (iii) the time period following the second chemical transition. Clarify why a K_d approach was used to simulate solubility control in PORFLOW, a code which allows specification of a solubility limit to limit dissolved phase concentrations without use of a K_d. Documentation should provide a transparent description regarding how solubility control is implemented in the PORFLOW model and point out any limitations in the approach used and any corresponding impact on performance assessment results (e.g., inability to simulate, or simulate a transition to, no solubility control).

CC-NF-4

In the discussion of dose results on pages 544-545 of the PA report, there are three apparent discrepancies between noted base case K_d values and the values listed in tables. Specifically:

- A Tc-99 soil K_d of 0.1 mL/g is mentioned, but the corresponding vadose zone value in Table 4.2-29 is 0.6 mL/g.

- An I-129 soil K_d of 0.6 mL/g is mentioned, but the corresponding vadose zone value in Table 4.2-29 is 0 mL/g.

- An initial Np-237 basemat K_d of 4,000 mL/g is mentioned, but the corresponding Oxidizing Middle Age value in Table 4.2-33 is 1,600 mL/g.

Clarify whether the values used in the analysis corresponded to the values in Tables 4.2-29 and 4.2-33. Note: The first two items discussed above apply to far-field parameters and are not repeated in the far-field comments.

CC-NF-5

In explaining the different PORFLOW and GoldSim Pu-239 curves in Figure 5.6-25 of the PA, the text refers to a 5,000 mL/g K_d for Pu. Table 4.2-33 of the PA indicates a value of 10,000 mL/g for Oxidizing Middle Age and a value of 1,000 mL/g for Oxidizing Old Age. Clarify what is the appropriate Pu-239 K_d value to consider in explaining the model differences.

CC-NF-6

The response to NF-19 noted that recommended K_d values were based not only on the specific, originally-cited experimental studies, but also on consideration of other data. The revised PA report noted the additional information. This response illustrated how DOE-sponsored studies at SRS have produced a great deal of valuable new information on the sorption and solubility behavior of radionuclides important to demonstrating compliance with performance objectives. It appears these laboratory studies are ongoing. NRC staff feels it would be useful for DOE to sponsor preparation of a compilation of all original sorption and solubility data produced at SRS in support of Waste Incidental to Reprocessing performance demonstration efforts. These data have arisen from both tank closure and salt waste disposal efforts. This data compilation would make more transparent the efforts DOE has sponsored to obtain, evaluate, and select data appropriate for use in performance assessment.

CC-NF-7

The response to NF-20 noted that the Tc K_d of 5,000 mL/g used for reducing cementitious media is considered "base case," rather than "conservative," and thus was chosen instead of the 1,000 mL/g "conservative" value of Bradbury and Sarott (1995). The 5,000 mL/g value is based on a single 1991 study, cited by Bradbury and Sarott that used a reductant not expected in reducing concrete or grout. Can the DOE describe any other, more recent data that would shed light on the appropriateness of this value? Alternatively, can the DOE demonstrate that the selection of this value is not significant to prediction of risk?

Reference

Bradbury and Sarott, 1995. "Sorption Databases for the Cementitious Near-Field of a L/ILW Repository for Performance Assessment," Revision 0. Paul Scherrer Institute, Labor für Entsorgung, Villigen PSI, Switzerland. March, 1995.

CC-NF-8

Revisions to the FTF PA to address the portion of comment NF-3 on the Revision 0 PA regarding the use of expert judgment in estimating uncertainty in the sorption coefficient provided a transparent rationale for the uncertainty in sorption coefficients on sandy and clayey soils. However, the revisions did not include a basis for inferring that the uncertainty in cementitious K_ds can be represented by the uncertainty in sandy soils.

CC-NF-9

The moisture characteristic curve utilized in the FTF PA for the grout, annulus, and contaminated zone within the PORFLOW model appears to be inconsistent with literature values for other cementitious materials (Rockhold et al., 1993; Savage and Janssen, 1997; and Baroghel-Bouny, 1999). Moisture characteristic curves are relied upon to determine the flow through unsaturated materials. The use of inaccurate curves for cementitious materials can artificially constrain infiltrating water, thereby delaying chemical transitions and reducing the flux of contaminants out of the tanks. DOE should use a more appropriate curve and indicate how the change in the curve impacts the dose results.

References

Baroghel-Bouny, V., Mainguy, M., Lassabatere, T., and Coussy, O., 1999. “Characterization and Identification of Equilibrium and Transfer Moisture Properties for Ordinary and High Performance Cementitious Materials,” Cement and Concrete Research, Vol. 29, pp. 1225-1238. 1999.

Rockhold, M. L., Fayer, M. J., and Heller, P. R., 1993. “Physical and Hydraulic Properties of Sediments and Engineered Materials Associated with Grouted Double-Shell Tank Waste Disposal at Hanford,” PNL-8813, Pacific Northwest Laboratory, Richland, Washington. September 1993.

Savage, B. M. and Janssen, D. J., 1997. “Soil Physics Principles Validated for Use in Predicting Unsaturated Moisture Movement in Portland Cement Concrete,” ACI Materials Journal, V. 94, No. 1, pp. 63-70. January-February, 1997.

CC-NF-10

There is ambiguity in the Revision 1 PA regarding the implementation of the “fast-flow” case or configuration D. For example, page 423 describes a fast flow case where *all* water deflected from the roof is shed along a vertical leg representing a fast flow case. The implementation of this case and presentation of this case in the PA is unclear. Either delete the text or identify where the results of this scenario are provided.

Page 439 of the Revision 1 PA indicates that the fast flow pathway is modeled in PORFLOW as a region of the basemat with no K_ds and in Goldsim with a portion of the flow bypassing the basemat with no K_ds with page 609 text indicating that up to 10 percent of the basemat was assumed to have no attenuating properties in the probabilistic assessment. On the other hand, page 587 states that PORFLOW models the fast flow pathway through the basemat with no retardation while Goldsim models the fast pathway with increased flow only. The barrier analysis presented in Section 5.6.7.3 of the Revision 1 PA also implements a partially failed basemat as having a channel with no flow impedance although chemical properties are assumed to be consistent with the base case (interpreted to mean that sorption occurs along the fast flow pathway). The inconsistent descriptions and treatment of the fast flow pathway through the basemat makes it difficult to determine how the basemat fast flow pathway is actually modeled in the deterministic and probabilistic models.

- DOE should clarify the treatment of the fast flow pathways through the tank and basemat in the PORFLOW, deterministic, and GoldSim, probabilistic models.

- DOE should explain the rather large difference in the PORFLOW versus Goldsim modeling results for Pu (see Figure 5.6-25 in the PA) which may possibly be attributed to the difference in treatment of the basemat by-pass fraction in the fast flow Configuration D.

CC-NF-11

DOE should explain the delay in Type IV cementitious material degradation and chemical transitions compared to other tank types. For example, complete hydraulic degradation for Type IV tanks in the base case takes 20,000+ years (see Table 4.4-5) and final chemical transitions do not take place until close to 20,000 years. Late chemical transitions occur even in the case when the tank grout is assumed to be completely degraded at time=0 years (Case 2) in the barrier analysis (see Table 5.6-76) indicating that late chemical transitions of Type IV tanks in comparison to other tank types is independent of cement degradation (i.e., indicates that slower transitions are due to slower flow rates through the Type IV tanks).

1. DOE should explain the longer times to cementitious material and chemical degradation of the tank grout in Type IV tanks compared to other tank types. It is expected that the long times to hydraulic degradation are a result of the lack of presence of cooling coils in the Type IV tank grout. However, it is less clear why the chemical transitions are delayed relative to other tank types for the barrier analysis case where the grout is assumed to be completely failed at time= 0 years.

2. If the delayed degradation times are due in part to the hydraulics of the system—due to shedding of infiltrating water from the roof of the Type IV tanks, then this phenomena should be more fully evaluated and presented in the PA as it represents a barrier to waste release and should have adequate support commensurate with its risk-significance. For example, if after cementitious material degradation, the properties of the cementitious materials (e.g., moisture characteristic curves) lead to flow impedance into the degraded tank grout compared to the surrounding soils, then the realism of the material property assignments of the cementitious materials and impact of the assumptions should be fully evaluated.

CC-NF-12

DOE should discuss in greater detail in-tank hydraulics that may significantly impact release rates from the tanks. For example, DOE discusses diffusion of radioactive constituents from the waste zone into the overlying grout prior to liner failure. It is not clear if this phenomena leads to a significant delay in the release of certain key radionuclides from the tank grout due to retardation.

DOE should indicate if diffusion or advection dominates waste release over time as the tank grout degrades over time for all tank types. Review of PORFLOW files seems to indicate that diffusion is the dominant transport mechanism at longer times after the tank grout is assumed to fail.

DOE should indicate the relative flow through the grout matrix versus through simulated fractures in Configuration D following grout degradation for all tank types. DOE should also indicate the relative amount of flow directly above the tank vaults that is transmitted through the vaults versus that portion of flow that is diverted around the tank vaults.

DOE should explain why the timing of the Pu peak dose changed from around 27,000 years in the Revision 0 PA to around 40,000 years in the Revision 1 PA. Part of the delay may be attributable to the 6,000 year delay in the final chemical transition as indicated in comment CC-NF-2.

NRC staff would like to meet with DOE to further discuss these and other questions it may have related to its review of the PORFLOW modeling files.

CC-NF-13

Text on page 581 of the PA indicates that DOE considered the drop panel in the center of Type III/IIIA tanks in PORFLOW modeling. Inclusion of this feature is inconsistent with Figures 4.4-2 and 4.4-3 and is stated to result in longer transition and travel times through the basemat for these tanks. The drop panel only exists below the center column and a small portion of the lined tank area. Provide additional information on the impact of the representation of the drop panel on the results of the analysis.

CC-NF-14

DOE should provide detailed information regarding known differences between the approach used to close Tanks 17 and 20 and current closure plans for remaining F-Area tanks that might impact the performance demonstration. For example, Tanks 17 and 20 were closed with a smaller volume of reducing grout and potentially different grout formulations than what is planned for other FTF tanks (DOE, 1997a; DOE, 1997b). DOE should also evaluate the impact of deviations between closure design features of Tanks 17 and 20 versus closure design features planned for remaining FTF tanks to ensure that PA assumptions regarding tank system performance are appropriate or bounding for the closed tanks.

References

DOE, 1997a. “Industrial Wastewater Closure Module for the High-Level Waste Tank 20 System.” PIT-MISC-0002, Revision 1. 1997.

DOE, 1997b. “Industrial Wastewater Closure Module for the High-Level Waste Tank 17 System,” PIT-MISC-0004, Revision 2. 1997.

Far-Field Comments

In the PA, DOE uses a far-field model to simulate the flow and transport of radiological constituents from the point of release outside the engineered tank system through the environment to various points of exposure where a receptor might be exposed. PORFLOW is used to simulate flow and transport in the far-field environment for the compliance case (i.e., Configuration A). PORFLOW is also used to simulate *flow only* for all other Tank Configurations. Far-field *transport* modeling is implemented in GoldSim for all tank configurations in the probabilistic analysis. Because GoldSim does not solve flow equations, flow velocities were calculated for use in GoldSim using PORFLOW model results. Risk-significant aspects of far-field modeling include assignment of natural system K_ds (e.g., clay lens in vadose and saturated zone) that impact the timing and magnitude of doses for key radionuclides and factors that influence groundwater dilution (e.g., infiltration rates, groundwater flow velocities and aquifer thickness). Thus, most of NRC's comments on the Revision 0 PA were related to assignment of natural system K_ds and aquifer dilution. Other comments on Revision 0 were related to calibration of the PORFLOW model to provide confidence in the modeling predictions, and benchmarking processes to align the Goldsim and PORFLOW models. DOE provided adequate responses to most of NRC's comments on the Revision 0 PA (see Table FF-1 below).

However, several new comments were developed during NRC's review of the Revision 1 PA. Many of these comments are related to NRC staff's review of a supporting reference (WSRC-TR-2007-00283) that indicates the presence of voids in the subsurface at FTF covering a significant fraction of the FTF footprint within the Santee formation or lower portion of the Upper Three Runs (UTR) aquifer. Several comments related to this feature are included in the far-field comments listed below. Other comments are related to NRC concerns regarding the treatment of hydrodynamic dispersion and concerns that numerical dispersion is limited to an acceptable level in DOE's PORFLOW model used in its compliance case. While significant new information was provided on DOE's benchmarking process, based on review of this new information provided in DOE's PA, NRC staff generated a number of follow-up comments related to the physical basis for the benchmarking factors applied to the GoldSim model (e.g., differences in the treatment of dispersion, vertical flow, or sorption between the more complex three-dimensional PORFLOW far-field model and the one-dimensional GoldSim model).

To develop the following comments, staff reviewed DOE's Revision 1 PA and supporting documents provided to NRC by letter dated April 2, 2010 (Gutmann, 2010). The staff's review criteria pertaining to far-field radionuclide transport are contained in Sections 4.2, 4.3.4, 4.4, and 4.6 of NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007).

Table FF-1 Crosswalk of NRC Far-Field Comments Resulting from Review of the Revision 0 PA to the New RAI Comments Based on NRC's Review of the Revision 1 PA

Old #	Subject	Response Adequate	Response Inadequate--Not Repeated	Cross-walk to New RAI/CC	Note
FF-1	K_d errors and ambiguity	X		CC-FF-7 CC-FF-9	Follow-up clarifying comment to determine which Pu K_d is used for far-field modeling, Pu (IV), Pu (V), or composite Pu K_d. Follow-up comment on C-14 sorption values based on SRNS-STI-2008-00445, Revision 0.
FF-2	Impact of cement leaching on K_ds			RAI-FF-4	Need for additional work in this area was noted in the comment response and Section 8.2 of the PA. NRC will continue to monitor DOE activities to study this issue. The comment is not repeated. A new comment related to geochemical impacts of grout leaching in the saturated zone was developed.
FF-3	Stormwater retention/ seepage basin plans	X			DOE will consider NRC comments regarding site drainage and ensure appropriate interface with CERCLA closure units as designs are finalized. NRC will continue to monitor these activities.
FF-4	Potentiometric surfaces	X			Sufficient information is provided in references.
FF-5	Explanation of what is shown on vadose zone calibration plots	X			
FF-6	Figure legend needed	X			
FF-7	Point of maximum groundwater concentration (100 m)			RAI-FF-5	Insufficient information is provided to determine the location of the center-line of the plume versus the 100 m compliance point (e.g., entry into Gordon aquifer could be downgradient of the 100 m compliance point in Figure 5.2-4).
FF-8	Continuity of tan clay	X			Response was adequate; however, conflicting information is provided in reference

					documentation regarding the continuity of the tan clay. Nonetheless, the Tan Clay Confining Zone (TCCZ) is modeled as a weak barrier to flow; therefore, the comment is not repeated.
FF-9	GoldSim model abstraction (cell representation)	X			Sufficient information was provided to determine the GoldSim model abstraction (i.e., discretization of saturated zone).
FF-10	PORFLOW model numerical dispersion.			RAI-FF-3	An additional RAI related to the appropriateness of porous media dispersion in the case of preferential pathways for fluid flow owing to Calcareous Zone dissolution was developed.
FF-11	GoldSim benchmarking	X		RAI-FF-6	DOE was responsive, but new information generated several new comments regarding the benchmarking process (follow-up comments).
FF-12	Aquifer thickness.	X			The DOE response was adequate.
FF-13	Darcy velocity.	X			Page 304 indicates that the flow in UTR is dependent on leakage to Gordon aquifer but is covered in uncertainty range. Darcy velocity should also be corroborated with contaminant transport data.
FF-14	K_ds for SZ			CC-FF-6	Insufficient information was provided in the PA to determine the material property assignments for the saturated zone—the text simply indicates it is dependent on location.
FF-15	K_d for Np and Pa in clayey sediment.	X		CC-FF-8	Response was adequate; however, new data obtained since PA Rev 1 lead to different Np/Pa saturated zone K_ds. Follow-up clarification regarding bounds for parameter distributions used in the PA was also needed.
FF-16	K_d for Tc	X			
FF-17	Higher resolution image map needed.	X			

RAI-FF-1

Explain and provide the technical basis for the hydrologic flow and transport modeling treatment of the variably grouted, Calcareous Zone in the lower zone of the UTR aquifer (i.e., UTR-LZ).

Basis:

Tanks 1–8 are located above subsurface voids located in the Santee Formation or lower zone of the UTR aquifer (WSRC-TR-2007-00283). Similar or more severe voids and cavities are located below tanks 25–28 and 44–47 (WSRC-TR-2007-00283). Voids were also found in the subsurface west of Tanks 17 and 19 within borehole DH-5, southeast of Tank 33 within borehole FSEPB6, and near the F Canyon within borehole FB1 (WSRC-TR-2007-00283). Voids found within exploratory boreholes beneath tank locations were filled with grout to provide for waste tank foundation support, but it stands to reason that many voids remain unidentified and open within the Calcareous Zone, which is expected to be present along the entire length of flow from the FTF to the 100 m compliance point in the lower zone of the UTR aquifer. In discussing this reference, the PA did not mention this seemingly very important and risk-significant subsurface feature (PA page 303).

Calcareous Zones that have undergone dissolution resulting in sinkholes and significant voids require special flow modeling treatment because the aquifer material has dual porosity and dual permeability characteristics due to the presence of both: (i) porous matrix and (ii) open conduits. The presence of open conduits may (i) potentially lead to preferential flow pathways through the subsurface, (ii) influence the location of the point of maximum exposure or compliance point, (iii) decrease transport times (leading to less decay of relatively short-lived radionuclides or transport of more slowly moving radionuclides to a receptor well within the 10,000 year compliance period), and (iv) lead to decreased natural attenuation (sorption) to subsurface materials due to a decreased solids to pore water ratio, complexation of key radionuclides (e.g., Pu) with elevated concentrations of carbonate, or non-equilibrium sorption due to the fast transport rates.

As an example of the potential magnitude of the problem, transport rates in karst aquifers can be rapid (as fast as several kilometers per day) and can cover large distances in relatively short periods of time (in excess of ten kilometers in less than a week) with little opportunity for dilution or attenuation of contaminants in the effluent (Worthington, 2007). Further adding to the complexity of the problem, variations in hydraulic head differences between matrix and saturated void space may lead to a situation where contaminant transport pathways may not be perpendicular to matrix head gradients—localized fluid piracy along discrete flow paths frequently occurs. Monitoring wells at the General Separations Area (GSA) will more often intersect matrix within the Santee Formation than UTR-LZ voids, and contaminant concentrations measured in the matrix may be lower than concentrations of constituents measured in a fast flow conduit. Thus, groundwater monitoring data near GSA source areas may be misleading and mask important flow and transport mechanisms operable at the site.

Path Forward:

1. Explain and provide a technical basis for the lack of consideration of potential open flow conduits within the Calcareous Zone of the lower zone of the UTR aquifer and

justification for the treatment of the grouted Calcareous Zones as unweathered sediments in the flow model.

2. Access the adequacy of characterization data along the flow path from the FTF to the 100 m and surface water compliance points in evaluating the potential impact of these zones on contaminant flow and transport.

3. Provide any tracer, contaminant migration, or characterization data that may shed light on the potential connectivity of these zones and potential impacts on contaminant flow and transport at FTF or the greater GSA (e.g., effects on hydraulic gradients, unexpected flow directions, or early break-through times of contaminant plumes). Monitoring data obtained from seeps or springs for natural or induced tracer studies would provide a better indication of the connectivity of these zones rather than monitoring data obtained from locations along flow paths of constituents in the aquifer that might hit or miss preferential pathways for fluid flow.

4. Provide support for the treatment of the Calcareous Zones as porous media in transport modeling in light of the fact that decreased solids and presence of high carbonate concentrations can lead to significantly higher mobility for key risk drivers such as Pu.

5. Provide reports cited in WSRC-TR-2007-00283 or WSRC-TR-99-4083, “Significance of Soft Zone Sediments at the SRS” that may contain additional information to evaluate the scope and magnitude of Calcareous Zone voids in the subsurface at FTF or along flow paths away from FTF including the following:

    - Mueser, Rutledge, Wentworth & Johnson Consulting Engineers, “Foundation Grouting New High-Level Waste Storage Tanks Building 241-14F Savannah River Plant,” October 1975.

    - US Army Corps of Engineers (COE), Charleston District, “Geologic Engineering Investigations, Savannah River Plant” Waterways Experiment Station, Vicksburg, MS, 1952.

    - WSRC (1999), “F-Area Northeast Expansion Report (U),” Site Geotechnical Services Department, Document No. K-TRT-F-00001, Revision 0, May, 1999.

    - WSRC (1998), “APSF Packaging and Storage Facility Soft Zone Settlement Analysis (U),” Site Geotechnical Services Department, Calculation No. K-CLC-F-00034.

    - WSRC (1995) “In-Tank Precipitation Facility and H-Tank Farm (HTF) Geotechnical Report,” Site Geotechnical Services Department, WSRC-TR-95-0057, Revision 0, 1995

    - Raytheon Engineers and Constructors, Ebasco Division, (1994), “In-Tank Precipitation Facility, Phase 1 and II Cone Penetrometer Studies,” Final Report, March 10, 1994.

6. Explain the potential impact of discharge of acidic waste in the F-Area and H-Area seepage basins on dissolution of subsurface materials and potential creation of preferential pathways from the basins to surface water as described in a DOE comment response to a Georgia Department of Natural Resources (GA DNR) comment in DOE's EIS for tank closure, DOE-EIS-0303 Appendix D (comment L-15-1 and L-15-2). Please provide Wike et al. reference WSRC-TR-1996-0279 from 1996 cited in the GA DNR comment. Note: The full citation for this reference was not provided with the EIS comment.

References

Millings, M.R., and G.P. Flach, 2007. "Hydrogeologic Data Summary In Support of the F-Area Tank Farm (FTF) Performance Assessment (PA)," WSRC-TR-2007-00283, Washington Savannah River Company, Savannah River National Laboratory, Aiken, SC. July 2007.

R.K., Aadland, et al., 1999. "Significance of Soft Zone Sediments at the SRS." WSRC-TR-99-4083. Westinghouse Savannah River Company, Savannah River Site, Aiken, SC. September, 1999.

Worthington, S.R.H., 2007. "Ground-water Residence Times in Unconfined Carbonate Aquifers," Journal of Cave and Karst Studies, v. 69, no. 1, p. 94–102. 2007.

DOE, 2002. "High-Level Waste Tank Closure, Final Environmental Impact Statement," DOE-EIS-0303. May 2002.

RAI-FF-2

Address apparent systematic deficiencies in the modeled representation of hydraulic heads within the UTR-UZ in Figure 4.2-17.

Basis:

The PA presents a comparison of the measured and simulated hydraulic heads in the UTR aquifer in Figure 4.2-17. The modeled hydraulic heads do not realistically capture the measured water table gradients. For example, the modeled hydraulic heads suggest a very steep gradient at the margins of the model domain where groundwater discharges to streams, and a very minor gradient within the interior of the GSA, which is dominated by the groundwater divide. The measured hydraulic heads, on the other hand, illustrate a much more gradual gradient throughout the entirety of the model domain. Deficiencies in capturing the behavior of the hydraulic gradient may affect the transport times as a function of distance from the tanks.

DOE acknowledges that comparison of expected travel times of constituents through the saturated zone in the area of interest was beyond the scope of the PA; therefore, the adequacy of the PA model with respect to accurately predicting contaminant flow and transport of constituents released from the FTF is indeterminate.

Improper flow modeling of the dual porosity/dual permeability Calcareous Zone may have contributed to relatively high residuals for the UTR-LZ (and UTR-UZ) in the study area and apparent systematic deficiencies in the modeled representation of hydraulic heads within the UTR-UZ in Figure 4.2-17.

Path Forward:

Explain the apparent systematic deficiencies in the modeled representation of hydraulic heads within the UTR-UZ in Figure 4.2-17, which DOE presented in its PA to provide confidence in flow model fidelity.

RAI-FF-3

DOE should provide a firm technical basis for the presumption that PORFLOW and GoldSim hydrodynamic and numerical dispersion are at acceptable levels, especially given the apparent importance of dissolutional features such as sink holes, voids, and conduits in the UTR-LZ aquifer.

Basis:

It is not clear that the amount of dispersion assumed in the FTF PORFLOW modeling for porous modeling is appropriate. Page 401 of the PA states a value of 10 m (10 percent of the 100 m length scale) and 1 m were selected for the longitudinal and transverse dispersivities. While the 10 percent rule is a good rule of thumb, given the great deal of information available on contaminant flow and transport at the site, the value selected for the dispersivity should be supported by site-specific observations of plume spread. Several groundwater modeling studies for the site have used a grid resolution similar to that selected for the FTF model but calibrated values of dispersivity are much more modest (e.g., 1.5 m for longitudinal dispersivity and ratios of 0.1 and 0.01 for transverse and vertical to longitudinal, respectively) even at much larger plume length scales. Furthermore, hydrodynamic dispersion is an appropriate concept for porous media modeling, but may not be appropriate for dual porosity/dual permeability modeling of transport through systems with significant voids resulting from carbonate dissolution.

As excessive hydrodynamic dispersion may have been simulated in the PORFLOW model, excessive numerical dispersion may have also occurred (smaller dispersivities necessitate finer grid resolution). Excessive hydrodynamic or numerical dispersion in both the PORFLOW and abstracted GoldSim modeling used to perform probabilistic analysis can lead to artificial dilution of contaminant concentrations (see also related concerns in RAI-FF-6). Hydrodynamic dispersion combined with numerical dispersion in the PA's porous media modeling, which assumes the Calcareous Zone is a competent sedimentary geologic unit instead of a system with significant sink holes, void space, and conduits, may lead to *excessive* dilution of contaminant concentrations (e.g., transverse and vertical dispersion may be minimal).

Path Forward:

Provide a firm technical basis for the presumption that PORFLOW hydrodynamic and numerical dispersion are at acceptable levels, especially in light of the apparent importance of dissolutional features such as sink holes, voids, and conduits in the lower zone of the UTR aquifer. DOE should provide analyses of any natural or induced tracer studies conducted at the seeplines surrounding GSA or other information to support its modeling approach. If insufficient information is available to adequately evaluate transport through the Calcareous Zone of the

UTR-LZ (Santee Formation), DOE should consider collecting additional information to better understand potential complexities of contaminant transport (e.g., travel times and concentrations) in the carbonate and calcareous aquifers below the FTF.

RAI-FF-4

In developing sorption coefficients for far-field radionuclide transport, it is not apparent that DOE considered the variably grouted, Calcareous Zone in the UTR-LZ aquifer.

Basis:

If radionuclide transport pathways from FTF cross variably grouted, calcareous strata, radionuclide sorption behavior may differ substantially from the conditions assumed when sorption coefficients (K_d values) were developed. Grouts in the subsurface could impose high pH, beyond the range considered for natural conditions. Elevated dissolved carbonate species in either old, carbonated cementitious materials or in the natural calcareous strata could significantly affect sorption behavior, particularly for actinides. It is not clear whether the range of sorption coefficients adopted for the performance assessment can account for these potential geochemical effects.

Path Forward:

Provide a technical basis for neglecting the variably grouted, Calcareous Zone in the UTR-LZ aquifer when developing sorption coefficients for far-field radionuclide transport.

RAI-FF-5

DOE should provide a stronger basis for the assumption that a compliance point located 100 m horizontally downgradient of the FTF boundary in each aquifer zone is sufficient for evaluating compliance with the 10 CFR Part 61 performance objective.

Basis:

Insufficient information is provided in the PA to evaluate the location of the centerline of a plume or plumes emanating from representative areas of the tank farm to assess the adequacy of the point of compliance. For example, Figure 5.2-4 may indicate that locations beyond 100 m may intersect with the highest concentrations emanating from the FTF in the Gordon aquifer (GA). Use of the 100 m location in assessing the relative concentrations in the GA versus UTR-UZ aquifer may bias the concentrations and doses low in the probabilistic analysis with the DOE having declared the selection of aquifer a key parameter in virtually every sensitivity analysis measure presented in Section 5.6 of the PA (the GA is assumed to be the most probable water supply aquifer but is also associated with the lowest aquifer concentrations in the probabilistic analysis).

Additionally, it is not clear if the PORFLOW modeling is accurately representing hydraulic gradients in the water table aquifer, making it difficult to evaluate whether the point of maximum exposure would occur in the UTR-UZ in the case where vertical gradients were low or in the UTR-LZ in cases where the vertical gradients might be larger in the real system (see also concerns raised in CC-FF-11). Maximum concentrations in the UTR-LZ due to relatively larger gradients may lead to overall lower concentrations and doses owing to greater dilution or due to intersection of the plume with clays along the flow path to the UTR-LZ (note that ambiguity exists in the treatment of clays in the SZ—see comment CC-FF-6 below). Thus, it is important to understand contaminant migration away from F-Area tanks to adequately evaluate DOE's selection of the point of maximum exposure in the aquifer system.

Path Forward:

More detailed flow modeling results in the immediate study area (i.e., just beyond the 100 m boundary) would greatly assist with evaluation of the PORFLOW far-field modeling results. More detailed figures illustrating the center-line of plumes emanating from various sources with the tank farm in comparison to the 100 meter compliance point are needed to adequately evaluate the sufficiency of the 100 m point of compliance.

Additionally, statements on page 304 in the Revision 1 PA appear to contain contradictory statements: "best-estimate predictions and field monitoring indicate that plume migration can be expected to occur through the UTR-UZ and UTR-LZ aquifer zones for travel distances through at least 100m" and "Contamination may or may not pass through the UTR-TCCZ before reaching the 100m perimeter." Please clarify the characteristics of contaminant flow and transport in the UTR aquifer which would ideally be based on information of contaminant transport from actual F-Area sources and reconcile these two apparently contradictory statements.

RAI-FF-6

Provide additional bases for the benchmarking process used to align GoldSim and PORFLOW modeling results. The benchmarking process may indicate a systematic deficiency with respect to the PORFLOW modeling and/or bias with respect to the results of the probabilistic modeling. Additional clarification and justification seems warranted to provide confidence in the PORFLOW and GoldSim modeling results.

Basis:

Benchmarking was conducted between the PORFLOW deterministic model and the GoldSim, probabilistic model used by DOE in the FTF PA. This process was informative as it also allowed limited independent verification of the accuracy of the PORFLOW model in representing major features of the engineered and natural systems at FTF. Initial adjustments were made to both models based on observations of model behavior and response gleaned from this process.

Ultimately, several final adjustments were needed to align the GoldSim model to the PORFLOW modeling results that resulted in significant decreases in the GoldSim modeled contaminant concentrations and dose. These adjustments were deemed necessary to facilitate comparisons between the deterministic and probabilistic models. Two factors were assigned in the GoldSim model. These benchmarking factors included an adjustment to the clayey fraction in the saturated zone cells of the GoldSim model and a plume correction and benchmarking factor applied to account for differences in hydrodynamic and numerical dispersion.

Since the impact of the application of these factors is rather significant (expected to approach an order of magnitude for moderate to highly sorbing constituents), NRC staff needs additional assurance that these factors are appropriately applied and are not an indication of a larger problem with the PORFLOW model that leads to significant underpredictions in the potential peak concentrations and dose associated with FTF releases in the base case. As recommended in FTF scoping meetings, the PORFLOW model should first be verified and validated to the extent practical with respect to the acceptability of the model to simulate major contaminant flow and transport processes operable at the FTF site prior to any benchmarking adjustments.

Path Forward:

Address the following items that require additional clarification or stronger bases:

1. Text on page 574 of the PA indicates that due to the heterogeneity of soils in PORFLOW versus GoldSim, clayey soil fraction was added to the GoldSim cells in the saturated zone to give some attenuating affect. This adjustment was one of the benchmarking parameters--the clay fractions assigned are 0.13 for the eastern portion of FTF and 0.25 for the western portion of FTF. Since the GoldSim model only represents flow through the UTR-UZ (before the TCCZ or Gordon Confining Unit are encountered) the clay fraction that is being simulated should not exist in the GoldSim representation. Explain the physical basis for assigning a clay fraction in the GoldSim model when no clay fraction appears to exist along similar flow paths being simulated in GoldSim in the PORFLOW model. If no physical basis can be provided, explain why PORFLOW results are considered more accurate than GoldSim results such that an adjustment to the Goldsim modeling results is necessary.

2. Regarding the assignment of a clay fraction in the GoldSim model, it is not clear how the clay fraction is assigned in GoldSim. For example, is the clay part of all cells or are a fraction of the total number of cells assumed to be clayey? If it is part of all cells, how are the K_ds treated—are they weighted averages? If so, this approach may not be valid as it would tend to bias the sorptive properties of the GoldSim cells high.

3. Text on page 575 of the PA indicates that a plume correction and benchmarking factor is applied to the GoldSim model to simulate the affects of dispersion in the more complex PORFLOW model and to compensate for other flow affects in the 3D model. The corrections are significant (i.e., 0.35 for Type I tanks and 0.3 for all other tanks or around a factor of 3). DOE should explain the physical basis for these corrections. For example, if the adjustments are needed to account for dispersion in higher dimensions, then DOE should evaluate if the amount of dispersion simulated in the PORFLOW model is appropriate (i.e., is numerical dispersion an issue or is hydrodynamic dispersion overstated)?

    a. Use tracer or contamination transport data comparisons to model simulations to illustrate the acceptability of PORFLOW modeling results with respect to dispersion (see comment RAI-FF-3 above).

    b. Provide additional information on the relative contributions of the GoldSim built-in plume correction function (to account for lateral dispersion) versus the additional benchmarking factor applied to the plume correction.

c. DOE could perform simulations assuming no physical dispersion in the PORFLOW and GoldSim models to see if the models consistently predict the plume center-line concentrations at downgradient locations (may need to adjust aquifer thickness in GoldSim to account for vertical transport into the UTR-LZ).

d. DOE could also perform scoping-level calculations using a finer grid resolution in the PORFLOW model to evaluate model construction impacts on simulation results to support its conclusions.

4. Related to the bullet above, text on page 575 indicates that differences in longitudinal numerical dispersion were mitigated through use of comparable sized cells. However, the PA indicates that 40 cells were used to simulate the saturated zone in GoldSim. The flow length is approximately 100 to 200 m from the tanks; therefore, the length represented in each cell is approximately 2.5 to 5 m, while the grid spacing in the PORFLOW model is approximately 15 m. Therefore this statement does not appear accurate. The fact that GoldSim had to be modified with a finer cell resolution and a clay fraction to obtain similar breakthrough times as compared to PORFLOW indicates that GoldSim results originally led to faster break-though times at significantly greater concentrations. Again, the bias between the GoldSim and PORFLOW modeling results is not clear and should be more fully explained to provide confidence in the deterministic and probabilistic modeling results.

    a. Regarding the plume correction and benchmarking factor, if the factor is needed to account for differences in flow, between the two models (i.e., PORFLOW simulates vertical as well as horizontal flow), then DOE should provide additional information on water balances between the aquifer zones that would account for these differences.

    b. Indicate if the benchmarking factors are based on comparison of GoldSim model results for the UTR-UZ or the UTR-LZ or a combination of both. While DOE assumes that the concentrations in the UTR-UZ and UTR-LZ are similar, additional support is needed to support this assumption (see comment CC-UA-2). If in fact, the UTR-LZ concentrations are significantly higher than the UTR-UZ concentrations (as may be indicated in Appendix F of the PA), then comparison of GoldSim concentrations with PORFLOW concentrations in the UTR-UZ may lead to a false conclusion that benchmarking factors that bias the results of the Goldsim model low are needed to align to PORFLOW modeling results for the UTR-UZ, while the center-line of plumes that may emanate from FTF are located in the UTR-LZ.

Clarifying Far-Field Comments

CC-FF-1

It was the recommendation of SRNL-ESB-2007-00008 that the following data be acquired and analyzed from at least one location associated with Tanks 1–8, 17–20, and 33–34, and at least one location associated with Tanks 25–28 and 44–47 to support the FTF PA:

- Conduct a cone penetrometer test (CPT) to the water table;
- Take a continuous core to the water table and produce a geologic log; and
- Take undisturbed samples from Shelby tubes within tank backfill and underlying undisturbed vadose zone soil (located based upon CPT and continuous core information) and perform standard geotechnical laboratory testing for hydraulic properties.

Indicate if any additional data based on these recommendations has been or will be collected. If more recent site-specific F-Tank Farm data have been obtained, present a comparison between the site specific data and the modeling parameters that justifies the use of the General Separations Area data for F-Tank Farm vadose zone modeling.

Reference

Jones, W., M. Millings, M. Phifer, 2007. "F-Area Tank Farm Vadose Zone Material Property Recommendations," SRNL-ESB-2007-00008, Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. February, 2007.

CC-FF-2

Provide documentation that demonstrates the use of CLSM as Tank Type IIIA backfill was limited (see page 316 of the PA) such that its neglect in vadose zone modeling is justified (CLSM backfill could focus infiltration through the waste zone). Alternatively, provide documentation that demonstrates the material properties of the CLSM now and in its future degraded state are sufficiently similar to the soil backfill material or sufficiently more permeable than the soil backfill material that its neglect in vadose zone modeling is justified.

CC-FF-3

Clarify the reason why there is a 0.6 m (2 ft) discrepancy between PA Table 4.2-23 and SRNL-ESB-2007-00008 Table 2 in terms of the distance between the basemats of Tanks 19 and 20 and the UTR-UZ water table. The PA seems to correct an error in the tank bottom elevations reported in Table 2 of SRNL-ESB-2007-00008 which is internally inconsistent with Table 1 of the same report. Please confirm the correct elevations for the tank bottoms and distance to the water table. Tank Group 2/Tank Type IV tanks have bottoms very close to the present-day water table surface such that a 0.06 m (2 ft) discrepancy can be significant given natural variations in groundwater levels.

Reference

Jones, W., M. Millings, M. Phifer, 2007. "F-Area Tank Farm Vadose Zone Material Property Recommendations," SRNL-ESB-2007-00008, Savannah River National Laboratory, Washington Savannah River Company, Aiken, SC. February, 2007.

CC-FF-4

Clarify the reasoning for the vadose zone modeling assumption that the compacted excavated soil backfill material underlying one-quarter of Tank 25 is modeled appropriately using the material properties of the lower vadose zone material.

CC-FF-5

Provide a documentary reference for the algorithm used to define the initial GSA/PORFLOW saturated zone model hydraulic conductivities and clarify if this is the conductivity as a function of mud content algorithm referred to in email correspondence between G. Alexander of NRC and G. Flach of DOE on October 18, 2010. WSRC-TR-2004-00106 mentions an algorithm for defining the initial GSA/PORFLOW saturated zone model hydraulic conductivity fields, which was also applied in the predecessor FACT model, but does not cite an appropriate reference for the documentation of this algorithm.

Reference

Flach, G. P., 2004. "Groundwater Flow Model of the General Separations Area Using PORFLOW," WSRC-TR-2004-00106, Revision 0, Savannah River Site, Aiken, SC. July 15, 2004.

CC-FF-6

Clarify material property assignments (K_ds) for the saturated zone. Page 304 in the PA states that the TCCZ is assigned the same K_ds as UTR. Page 339 of the PA indicates that the assignment of saturated zone K_ds is variable, dependent on location. Benchmarking indicates that a clay fraction is added to the GoldSim model to account for a clay fraction in the PORFLOW model. Yet, clay material assignments are not clearly indicated.

CC-FF-7

Provide a basis for the C-14 K_ds selected for use in the PA. Sorption of C-14 as carbonate to various cementitious and aquifer materials is expected to be kinetically limited based on information provided in SRNS-STI-2008-00445, Table 5. DOE should justify use of K_ds representative of C-14 equilibrated for a period of 6 months. Travel times through the natural system are expected to be more rapid with the potential for non-equilibrium sorption. K_ds for shorter equilibration times are much less than they are for the 6 month equilibration times and may be more appropriate.

Reference

Roberts, K.A., and D.I., Kaplan, 2008. "Carbon-14 Geochemistry at Savannah River Site," SRNS-STI-2008-00445, Revision 0, Savannah River National Laboratory, Savannah River Nuclear Solutions, Savannah River Site, Aiken, SC. December 2008.

CC-FF-8

SRNL-STI-2009-00634 reports a lower Np clay K_d value of 9 versus 35 L/kg used in the base case configuration, while the sand K_d increased. The Np K_d used in the probabilistic analysis is reported to range from 70 (min) and 42 L/kg (max). Since Np is a risk driver, DOE should evaluate the impact of use of updated K_d information on the base case results and clarify the actual values used in the probabilistic analysis (as well as consider changes to the clay K_d distribution in the probabilistic analysis based on the new information).

Reference

Kaplan, D. I., 2009. "Neptunium IV and V Sorption to End-Member Subsurface Sediments of the Savannah River Site," SRNL-STI-2009-00634, Savannah River Site, Aiken, SC, Rev. 0, November 2009.

CC-FF-9

DOE should clarify use of Pu K_ds in the PORFLOW modeling. K_ds are provided for various oxidation states of Pu, including Pu (IV), Pu (V), and a combined oxidation state Pu. The relatively large K_ds for the combined Pu would lead to slower transport times and decreased concentrations at the compliance point in the base case that occur well beyond the compliance period of 10,000 years compared to lower values. Probabilistic analysis results indicate a threshold Pu K_d where under certain conditions, Pu can be transported to an aquifer well within 10,000 years at doses an order of magnitude greater than the compliance limit. Thus, a smaller fraction of more mobile Pu could lead to exposures within the compliance period. The method of averaging K_ds for the various oxidation states should be justified. Furthermore, given the risk significance of this parameter, the experimental conditions should be clearly representative of the conditions expected in the field and corroborated with site-specific information on Pu transport rates.

DOE should evaluate the impact of a more mobile fraction of Pu being transported in the saturated zone or provide a strong basis for why the approach taken is acceptable (e.g., representativeness of experimental conditions to describe Pu transport and acceptability of K_d averaging process). It is important to note that depending on the answer to this clarifying comment, the comment may have been more appropriately labeled an RAI. NRC anticipates that DOE will respond at a level commensurate with the risk-significance of this comment.

CC-FF-10

DOE should indicate how it calibrated the far-field PORFLOW model to saturated flow and transport times of contaminants. Because calibration to head alone can result in non-unique solutions, DOE should demonstrate that its base case far-field model accurately represents the GSA groundwater flow system. DOE should provide comparisons of model-predicted transport times and flow directions using information from references such as the recently completed composite analysis or other documentation that may contain this type of information to demonstrate that the PORFLOW model accurately represents reality.

Figure 4.4.40 of the PA compares pathlines from the PORFLOW model versus plumes emanating from F-Area. No reference is provided for the depicted plumes, making it difficult to evaluate the accuracy of plume projections and the ability of the PORFLOW model to adequately simulate groundwater flow and transport processes in the area of interest (e.g., information on plume source origins and areas would be helpful when comparing modeled particle tracks to plume distributions). Provide (i) the reference for the plume depictions and (ii) any supporting characterization and groundwater characterization/modeling reports related to known F-Area and H-Area plume sources documented in DOE-EIS-0303 (2002) Table 3.2-1 listed below.

1. Burial Ground Complex Groundwater and Radioactive Waste Disposal Facility
2. F-Area Coal Pile Runoff Basin
3. F-Area Hazardous Waste Management Facility
4. F-Area Retention Basis
5. F-Area Seepage Basin Groundwater Operable Unit
6. F-Area Burning/Rubble Pits

Provide the report entitled “Groundwater Model Calibration and Review of Remedial Alternatives at the F- and H-Area Seepage Basins,” written by GeoTrans under contract with Westinghouse Savannah River Company Environmental Restoration Group dated July 1993.

Reference

DOE, 2002. “High-Level Waste Tank Closure, Final Environmental Impact Statement,” DOE-EIS-0303. May 2002.

CC-FF-11

NRC staff noted differences in the hydrogeological conceptual models presented in the PA versus those presented in previous tank closure documentation (DOE, 1997a and DOE 1997b) and the tank closure EIS (DOE, 2002). For example, the closure documentation appears to indicate that groundwater flow from the FTF is towards Fourmile Creek. The EIS documentation seems to indicate that groundwater flow towards Fourmile Creek is primarily horizontal in the upper aquifer zone with an upward potential existing from deeper to shallower groundwater. DOE should clarify the evolution of the hydrogeological conceptual model for the FTF and indicate how uncertainties with respect to flow directions and gradients might impact the compliance demonstration.

References

DOE, 1997a. “Industrial Wastewater Closure Module for the High-Level Waste Tank 20 System,” PIT-MISC-0002, Revision 1. 1997.

DOE, 1997b. “Industrial Wastewater Closure Module for the High-Level Waste Tank 17 System,” PIT-MISC-0004, Revision 2. 1997.

DOE, 2002. “High-Level Waste Tank Closure, Final Environmental Impact Statement,” DOE-EIS-0303. May 2002.

Performance Assessment Overview

This section contains comments on the general issues associated with the development of Revision 1 of the FTF PA.

NRC staff has evaluated DOE responses to NRC comments on the Revision 0 PA as part of its evaluation of the PA Revision 1. Table PA-1 identifies whether the responses provided were adequate or inadequate. Comments with inadequate responses remain open. For some comments, NRC staff also determined that an inadequate response required follow-up via a Request for Additional Information for significant information or a clarifying comment for information with lesser significance. The table identifies related follow-on RAIs and clarifying comments that are listed below. One new comment related to the conservatism of the base case analysis was developed and is supported by several related RAIs and comments found in other sections of this document. NRC recommends DOE consider the comments in aggregate in making a decision to update its base case scenario and compliance demonstration. As appropriate, DOE should also note areas of future work necessary to strengthen the technical basis of its PA and associated compliance demonstration.

To develop the following comments, staff reviewed the revised PA and supporting documents provided to NRC by letter dated April 2, 2010 (Gutmann, 2010). The staff's review criteria pertaining to near-field release of radionuclides are contained in Sections 4.1, 4.2, 4.4, and 4.6 of NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007).

Table PA-1 Crosswalk of NRC Performance Assessment Comments Resulting from Review of the Revision 0 PA to the New RAI Comments Based on NRC's Review of the Revision 1 PA

Old #	Subject	Adequate	Inadequate (Not Repeated)	Follow-up Comment ID	Note
PA-1	FEPs		X	RAI-PA-2	
PA-2	Seismic Impacts			RAI-SS-1 RAI-SS-2 RAI-SS-3	New comments related to seismic analysis.
PA-3	Colloidal transport	X			Noted in future work. NRC will continue to evaluate this issue during the monitoring phase.
PA-4	Corrosion and degradation product impact on colloid migration		X	CC-PA-1	
PA-5	Peak dose & defensibility of timing and magnitude of peak dose	X			
PA-6	Barrier Analysis	X		CC-PA-2 through CC-PA-8	Additional information (i.e., barrier analysis) was provided. Follow-up comments pertain to new information.
PA-7	Affect of admixtures on grout degradation	X			
PA-8	Capture peak dose	X			
PA-9	Discrepancies in flux	X			
PA-10	Ra-226 dose spike attributable to U-234 not U-238	X			

RAI-PA-1

DOE should evaluate the conservatism of the base case scenario in the revision 1 PA in the presence of large uncertainty.

Basis:

In addition to the many RAIs and clarifying comments on the Revision 1 PA that speak to the lack of consideration of important features, events, and processes in the base case analysis that may lead to significant under-predictions of the peak dose within the compliance period or beyond, NRC staff does not agree that the following items represent conservatisms in the base case modeling as indicated in Section 7.2 of the Revision 1 PA.

1. DOE indicates that the inventory developed for the PA is conservative based on the following:

a. Use of the waste characterization system (WCS) that tends to overestimate the inventory due to assumptions regarding burn-up levels and over-estimation of the presence of PUREX low-heat waste rather than cladding waste. While the WCS may provide what is considered conservative estimates of inventory in some cases for the reasons cited, NRC noted in previous comment on the Revision 0 PA that WCS also appears to underestimate the concentrations of key radionuclides (e.g., Cs-137, Tc-99, Np-237) by orders of magnitude in some cases. Thus, the conservatism of the WCS concentrations has not been clearly demonstrated.

b. Potential over-estimation of concentrations following treatment with oxalic acid. NRC notes in previous comment on the Revision 0 PA that oxalic acid has also been found in DOE studies to potentially concentrate key radionuclides Pu and Sr in the waste.

c. Use of concentrations a factor of 10 higher than assumed in the Revision 0 PA. As noted in previous NRC comment on the Revision 0 PA, DOE did not provide support for its initial assumption that residual waste could be removed down to 1/16 of inch or around 0.0625 inches for all tank and waste types. For example, Type IV tanks 18 and 19 are estimated by DOE to have a residual volume greater than 10 times or greater than 0.6 inches of residual waste remaining in the tanks. Therefore, while the factor of 10 increase in the assumed inventory in the Revision 1 PA may be adequate, in some cases, as illustrated above, the assumption is not clearly conservative.

2. DOE indicates that the Revision 1 PA is conservative in a number of areas with respect to the cover performance and degradation modeling. NRC does not agree that the cover performance and degradation modeling is demonstrably conservative. The simplified modeling approach may not account for a significant number of factors that may override stated conservatisms due to the tendency of the model to average processes and/or be overly optimistic with respect to as-emplaced conditions. NRC staff also note the lack of experience and support for the long time periods relied on for performance of the engineered barrier in the literature.

3. With respect to the integrated site conceptual model,

a. DOE notes that the assumption that the steel liner corrodes from both sides is conservative but as indicated in RAI-NF-4, it is not clear that this is the case.

b. DOE notes that the transfer line release modeling is conservative as the transfer lines are assumed to be failed after the first pit penetrates. As indicated in NRC comment RAI-NF-5, it appears that the assumption is that 25 percent of the area must be breached prior to transfer line failure.

c. DOE notes that solubility treatment is conservative with respect to the selection of solubility limiting phase. DOE also notes that the selection of a discrete radionuclide phase rather than iron co-precipitation is conservative. These statements appear misleading; as DOE does, in fact, use the iron co-precipitation model that is the subject of several NRC comments (e.g., RAI-NF-8 and RAI-NF-9).

d. DOE notes that the waste release model does not credit any additional potential contaminant retardation mechanisms, such as retardation associated with iron oxides/hydroxides from the corroded waste tank liner. NRC would also note that the inventory associated with several key radionuclides is assumed to be co-precipitated with iron so the conservatism of this assumption is not clear. Furthermore, the affect of corrosion products on colloidal transport was not considered as indicated in CC-PA-1 below.

Path Forward:

DOE should consider NRC RAIs and clarifying comments presented in this document and in this RAI and revise Section 7.2 as appropriate.

DOE should consider updating its base case scenario considering the totality of NRC comments presented in this RAI package to ensure that its compliance demonstration is sufficiently robust considering the level of uncertainty inherent the PA calculations over the long-time periods relied on for performance. For those technical issues that DOE is not able to address during the comment resolution period, DOE should indicate those areas of its PA that may require additional support and provide recommendations on how this additional support will be obtained in the future in Section 8.2 of the PA on future work.

RAI-PA-2

DOE should clarify its process for identification and evaluation of features, events and processes that affect disposal facility performance and provide results of its evaluation process including a listing of features, events, and processes that DOE SRS has considered but excluded from the FTF PA documentation and the basis for the exclusion.

Basis:

The Calcareous Zones that have undergone extensive dissolution and grouting underneath significant portions of the FTF footprint are considered by NRC staff to be a potentially very risk-significant feature of the disposal facility. However, the presence of the significant and variably grouted void areas in the subsurface at FTF was not discussed during FTF scoping, nor was it discussed in the Revision 0 and Revision 1 FTF PAs.

Path Forward:

Indicate DOE's process for identifying and evaluating FEPs and indicate if there are other potentially risk-significant FEPs that were not discussed in the PA. DOE should indicate if these FEPs were evaluated and eliminated from consideration in the PA or if future work is planned to address the FEPs.

Clarifying Performance Assessment Overview

CC-PA-1

In response to PA-4, no basis for the likelihood or consequences of corrosion products or cementitious material degradation products was provided. Provide a basis for lack of consideration of colloidal transport facilitated by the presence of corrosion or cementitious material degradation products.

CC-PA-2

The barrier analysis did not evaluate the capabilities of the natural system. DOE should consider updating its barrier analysis to address by-passing of the natural system due to chemical effects or due to the presence of Calcareous Zones in the subsurface, for example.

CC-PA-3

The barrier analysis does not evaluate the capabilities of the tank system against inadvertent intrusion. DOE should consider expanding its barrier analysis to evaluate the importance of various barriers to human intrusion.

CC-PA-4

The barrier analysis should consistently consider impacts to both the magnitude of the changes in peak indicator (i.e., flux, dose, etc.) and changes in the timing of that indicator in evaluating the capabilities of a particular barrier, as appropriate. Some barriers have capabilities that delay the release of radionuclides while others limit the magnitude of the release. This analysis confuses the significance of each distinct barrier capability in some insights. For instance, Section 5.6.7.3.4.2 indicates that the liner has minimal impact as a barrier. This appears to be an erroneous conclusion because the analysis focuses on the change in magnitude of the indicator rather than the effect on timing. The liner's main capability is to delay all releases, which is intuitive since fluxes cannot occur until after the liner fails.

CC-PA-5

The analysis appears to analyze cases which are inconsistent. For instance, 7 of 15 cases (i.e., Cases 1, 3, 4, 5, 6, 7, and 8) involve failed grout and nominal contaminated zone capabilities. Failed grout is represented by high flow throughout the grout causing it to impart reducing conditions onto the contaminated zone. Whereas, a nominal contaminated zone is represented by base case solubility limits. Clarify how the failed grout condition impacts contaminated zone capabilities.

Also, there are cases in which the grout is failed and the contaminated zone is failed (i.e., Case 12) or partially failed (i.e., Case 13). In Case 12, a failed contaminated zone is represented by solubility limits associated with *oxidized* region III while the failed grout imparts *reducing* conditions to the contaminated zone. Similarly, in Case 13, a partially failed contaminated zone is represented initially by solubility limits for oxidized region II while the failed grout imparts reducing conditions on the contaminated zone. Clarify the evolution of chemical conditions for these cases.

Provide a concise description of each case to improve clarity of actual conditions being represented and reveal potential physical inconsistencies. Identify correlated barriers and where appropriate ensure all pertinent combinations of hydraulic (with and without fast flow) and chemical performance are evaluated.

CC-PA-6

Representation of the tank concrete as a single barrier limits an understanding of the distinct capabilities and performance of the various tank concrete components. For instance, the tank vault roof concrete is generally expected to be a barrier to flow through the system while the basemat is more significant as a barrier to radionuclide transport. The analysis should develop an understanding of the various components capabilities to limit water flow (e.g., hydraulic) and radionuclide migration (e.g., chemical). This should include an evaluation of bypass of the attenuating (sorption) properties of the basemat.

CC-PA-7

Clarify the following results or correct the following errors in the revision 1 PA barrier analysis and indicate if any identified errors affect the results of the analysis:

1. The last bullet for Tank 5 (Pu-239) insights on Page 708 regarding Cases 5 and 6 is not clear. Provide a description of why Case 6 (i.e., fast flow path through concrete) would result in a lower flux than Case 5 (i.e., intact concrete).

2. The characteristics of failed "grout" are that reducing capacity is imparted on the contamination zone. If chemical barrier affects are being simulated, then the "grout" barrier description should have more precisely indicated that the grout imposes high pH conditions, as well as reducing capacity to the contamination zone. Similarly, partially failed grout should not lead to high pH buffering of the contaminated zone. Clarify if these omissions were inadvertent (i.e., confirm that DOE considered partially failed grout as imparting no chemical benefit to radionuclide retention including buffering the contaminated zone to high pH).

3. Figure 5.6-76 appears inaccurate for Case 14 which represents the nominal case for each barrier except the contaminated zone which is represented as partially failed. According to Table 5.6-22, partially failed contaminated zone would transition to Region III after 2,063 pore volumes, whereas Figure 5.6-76 displays that the contaminated zone is Region III initially.

4. The text on page 739 incorrectly states that partially failed "grout" has the same chemical properties as in the base case. Partially failed grout has a fast flow pathway with no flow impedance and leads to a situation where the contamination zone is not conditioned by the reducing grout.

5. The last sentence on page 739 is incorrect. It should state that the partially failed grout in Case 11 leads to higher doses than Case 2 which represents *completely failed grout*.

6. Table 5.6-25 indicates that Case 3 is 1E-06 lower than Case 2 but Figure 5.6-79 illustrating the same results does not indicate this. Indicate whether the figure or table is correct.

CC-PA-8

While the barrier analysis represents a significant improvement to the performance assessment, some cases and results are either ambiguous or not intuitive making it difficult to understand and interpret the results of the analysis. For example, the following confound understanding of the implementation and/or interpretation of the results of the barrier analysis:

Solubility limits do not always increase following a chemical transition making it difficult to interpret the impact of the barrier "contamination zone". If the primary attribute of the barrier "contamination zone" is a limit on aqueous phase concentrations due to the imposition of solubility limit constraints, then a partially failed or failed contaminated zone should result in a corresponding increase in the solubility limit compared to the base case. In contrast, the barrier analysis implements a partially failed contaminated zone case where the solubility of key radionuclides contributing to peak dose dominated by iron co-precipitation actually decreases from the base case. Consider implementing the partially failed and failed contaminated zone as having progressively increased solubility or clarifying how the approach taken leads to non-intuitive results due to the decrease in solubility following the first chemical transition for certain radionuclides.

Uncertainty/Sensitivity Analysis

The purpose of DOE's probabilistic analysis is to evaluate the range of potential doses that might result considering variability and uncertainty in PA modeling parameters and processes, as well as to identify important model sensitivities. The probabilistic analysis was conducted using Monte Carlo techniques readily available in the GoldSim modeling platform via simulation of a set of configurations representing various states of potential engineered barrier performance, as well as by propagating uncertainty in common parameter values for all configurations. Because DOE evaluates facility compliance with performance objectives for low-level waste disposal found in 10 CFR Part 61, Subpart C based on a deterministic model using a base case scenario identified as Configuration A in the PA, sufficient support for the base case configuration is considered essential by NRC staff to DOE's compliance demonstration. Additionally, if alternative configurations (e.g., Configurations B-F in the PA) are just as or more likely to occur as Configuration A or insufficient information is available to determine the likelihood of any particular configuration, then NRC staff recommends that DOE present and consider results for the subset of the most likely configurations or select a configuration that clearly tends to over- rather than under-estimate the potential dose when demonstrating compliance with the performance objectives. As discussed in the near-field comments, it is NRC staff's position that Configurations A through F represent certain aspects of facility performance that may all contribute to a better understanding of actual facility performance. Configurations A through F are not mutually exclusive and more than one feature or aspect of the system being modeled may occur in the real, highly dynamic, and complex system being modeled. Therefore, NRC staff also encourages DOE to evaluate potential events that were not considered in its base case but that may, nevertheless, occur. Some of these events may have been captured in Configuration D or E results but were not considered as part of the base case (e.g., by-pass flow albeit at potentially lower fluxes earlier in the compliance period or earlier waste release from the system due to accelerated corrosion due to adverse conditions such as wetting and drying of Type IV tank bottoms).

The majority of the comments on the Revision 0 PA were related to the potential for certain assumptions and approaches taken in the PA to skew the results or significantly reduce the peak of the mean dose including assignments of configuration probability or important parameter distributions (e.g., steel liner failure times, K_ds and solubility limits). Other comments included lack of transparency of modeling approaches and results (e.g., lack of presentation of results for individual configurations). Because the software program GoldSim was used to perform the probabilistic uncertainty analysis and GoldSim represents a simplified version of the deterministic modeling conducted using the PORFLOW code, several comments related to the model abstraction and benchmarking processes used to simplify and align PORFLOW to GoldSim modeling results, respectively, were developed.

While significant improvements were made to the probabilistic uncertainty and sensitivity analysis in the revised PA, including presentation of results for the highest consequence realizations, a new and improved sensitivity analysis that clearly identifies parameters important to peak dose, and a barrier analysis that provides useful information about the contributions of individual components of the engineered system to performance, several comments NRC staff made on the Revision 0 PA were not incorporated in the revised PA. Some of these comments were repeated below, while others were not. Table UA-1 below provides a cross-walk between the old and new comments. Repeated comments on the Revision 1 PA include a request for presentation of results for Configurations E and F, which were requested after review of the

Revision 0 PA but were still not included in the revised PA. NRC staff also note that while significant effort was made to evaluate barrier contributions with respect to their impact on the magnitude of peak dose, specific results requested by NRC staff on the Revision 0 PA to study the impact of parameters on the timing of peak dose received considerably less emphasis. Because compliance with the performance objectives in 10 CFR Part 61, Subpart C is typically evaluated over a compliance period of 10,000 years, barriers that affect the timing of releases are very important to the compliance demonstration. In fact, if timing of peak dose is ignored, the PA indicates that the dose limit of 25 mrem/yr (0.25 mSv/yr) could be exceeded by over an order of magnitude in the base case for what DOE deems the most likely configuration. Thus, barriers that delay the timing of the peak dose are extremely important to the compliance demonstration. Additionally, DOE's probabilistic analysis indicates doses greater than 10,000 mrem/yr (100 mSv/yr) for what is expected to be low probability conditions. Thus, a good understanding of these low probability/high consequence realizations is important to managing disposal facility risk to ensure that especially risky disposal facility configurations will not occur and that measures are taken to mitigate the potential risks if consistent with ALARA criteria.

To develop the following comments, staff reviewed the PA and supporting documents provided to NRC by letter dated April 2, 2010 (Gutmann, 2010). The staff's review criteria pertaining to the approach to sensitivity and uncertainty analysis are contained in Sections 4.2, 4.4, 4.5 and 4.6 of NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007).

Table UA-1 Crosswalk of NRC Uncertainty and Sensitivity Analysis Comments Resulting from Review of the Revision 0 PA to the New RAI Comments Based on NRC's Review of the Revision 1 PA

Old #	Subject	Adequate	Inadequate (Not Repeated)	Follow-up Comment ID	Note
UA-1	Risk dilution	X		RAI-UA-2-	Did not perform sensitivity analysis on timing of peak dose. Less emphasis was placed on attributes of barrier performance that delay the timing of peak dose.
UA-2	Treatment of solubility and K_d uncertainty			RAI-NF-10 RAI-NF-11 CC-NF-8	Follow-up comments related to use of professional judgment in assigning K_d and solubility parameter distributions.
UA-3	Comparison of deterministic to stochastic analysis at time of peak.	X			
UA-4	Barrier analysis. Presentation of results for configurations. Ambiguity in configurations and results. Lack of consideration of natural system barriers.			RAI-UA-4 CC-PA-2 RAI-NF-15	No results were presented for Configurations E and F. No results were presented for the natural system in the barrier analysis. Condition 2 was eliminated from consideration in the Revision 1 PA without justification.
UA-5	Evaluation of multiple system failures. Maximum realizations.	X		CC-UA-3 RAI-NF-15 CC-PA-2	While the barrier analysis represents a significant enhancement to the uncertainty and sensitivity analysis, evaluation of barrier performance was not comprehensive (e.g., Condition 2). Natural system performance was not evaluated.
UA-6	Benchmarking			RAI-FF-6	
UA-7	Justification for configuration probabilities and construction of			RAI-UA-1 RAI-UA-3 RAI-UA-4 RAI-PA-1	Several follow-up comments were developed related to support the base case analysis and configuration probability.

	UA/SA.				
UA-8	Parameter correlations.		X	Several related comments.	Parameter correlations were not considered and in some cases lack of consideration of correlations may skew the results of the probabilistic analysis (e.g., biosphere parameters that are clearly correlated). In the worst case, lack of consideration of parameters may lead to technically indefensible assumptions in the base case (e.g., lack of correlation of parameters and processes related to cementitious material and steel liner degradation modeling). See comments in near-field for specific examples.
UA-9	Four parameters listed in SI results.	X			
UA-10	Limitations of gradient boosting model.	X			
UA-11	Non-intuitive result with Darcy velocity.	X			

RAI-UA-1

DOE should provide a defensible basis for the likelihood of alternate configurations in the PA

Basis:

Section 5.6.3.1 states that discrete distribution of likelihoods for alternate configurations were chosen using engineering judgment. The section lists how tank design differences informed the probability choices in a qualitative way, but is neither transparent nor traceable in how the quantitative values were estimated based on qualitative considerations. Quantitative estimation of the likelihood may not be directly possible. The likelihood of the alternate configurations is significant in understanding the uncertainty in the performance of the tank system. Therefore, the uncertainty analysis is likely biasing results indeterminately.

Path Forward:

Provide a defensible basis for the likelihood of alternate configurations. One possible approach would be to perform a formal expert elicitation (e.g., NUREG-1563) process to estimate the likelihoods. Another approach would be to report the expected result and associated uncertainty for each configuration independently and discuss the rationale for the likelihood of each scenario so that the information is transparent to the DOE decision-maker.

Reference

Kotra, J.P., et al., 1996. “Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program,” NUREG-1563, US NRC, Washington, DC. November 1996.

RAI-UA-2

DOE should use its probabilistic analysis results to perform a sensitivity analysis with respect to the timing of peak dose.

Basis:

Some barriers simply serve to delay the timing of the peak dose and most notably delay the timing of the peak dose beyond the 10,000 year compliance period rather than having a strong affect on the magnitude of the peak dose. These barriers are nonetheless important to the compliance demonstration and should receive equitable treatment in the probabilistic uncertainty and sensitivity analyses.

The barrier analysis clearly shows that if the steel liner performs as well as assumed in the base case analysis, the steel liner can have a significant impact on the reducing the magnitude of the peak dose that occurs within the 10,000 year compliance period compared to a case where the steel liner is assumed to fail early. In fact, because the base case steel liner failures times for Type I and III/IIIA tank types all fall beyond the 10,000 year compliance period, it is impossible for tanks of these types to contribute to an exceedance of the dose criteria within the compliance period. In other words, steel liner failure times serve to delay the timing of the peak dose beyond the assumed period of compliance for most tank types and while the peak dose from these tanks may well exceed the performance criteria, these results are not considered in the compliance demonstration. While DOE attempts to justify the low likelihood of relatively early steel liner failures within the compliance period, several NRC comments in the near-field section question the support for the assumed steel liner failure times in the deterministic analysis and while many comments on the Revision 0 PA are not repeated, several comments in the Revision 0 PA questioned the support for the steel liner failure time distributions assumed in the probabilistic analysis that also served to skew the results (e.g., less than one percent of assumed failure times were assumed to occur within 10,000 years for Type I and III tanks).

Path Forward:

Present results of a sensitivity analysis using endpoints related to the timing of peak dose to evaluate those parameters that have the greatest impact on DOE’s compliance demonstration.

RAI-UA-3

Speak to the results of the PA modeling that indicate that the dose limit in 10 CFR 61. 41 can be significantly (one order of magnitude or more) exceeded in its base case scenario at some point in the future.

Basis:

While the results of the base case and probabilistic modeling indicate that the 10 CFR 61.41 performance objective will not likely be exceeded within the 10,000 year period of performance, the results do indicate that the dose limits will be significantly exceeded (order of magnitude or more) considering longer periods of performance. Furthermore, there appears to be significant uncertainty with respect to the timing of the peak dose (see RAI-UA-2 for example), while there is much less uncertainty associated with the results that indicate the dose limit will exceeded at some time in the future.

Barrier analysis results presented in Section 5.6 of the revised PA also indicate a relatively high probability of Np exceeding the dose criterion for the base case scenario within 10,000 years with virtually all cases indicating a significantly higher Np flux if barriers do not perform as well as expected. In light of these results, DOE should speak to the apparently greater risk that Np alone could cause an exceedance of the dose criterion within the 10,000 year compliance period.

Path Forward:

Clarify how DOE intends to consider the results of the PA modeling that indicate the doses can greatly exceed the performance objectives in 10 CFR Part 61, Subpart C over longer compliance periods and within the compliance period considering uncertainty. DOE should specifically address these results in its Criterion 2 and ALARA evaluations, as appropriate.

DOE should indicate in stronger terms its confidence that Np doses will not exceed the 25 mrem/yr (0.25 mSv/yr) dose criterion within the compliance period in light of the fact that almost all of the barrier analysis runs indicate that underperformance of any barrier is likely to lead to a significant increase in the Np dose. DOE should specifically evaluate statistics surrounding the Np dose in the probabilistic modeling and identify parameters most important to Np dose.

RAI-UA-4

DOE should present results for Configuration E and F analyzed in the Revision 1 PA.

Basis:

The Revision 0 PA indicated that the selection of Configuration E (water table rise) and F (soil cover) could represent relatively higher risk configurations for the tank system (see for example page 611 of SRS-REG-2007-00002, Revision 0). NRC comments on the Revision 0 PA requested presentation of results for these alternative configurations. Configuration E and F represent configurations aspects of which are not reflected in Configurations A-D. Yet, DOE neglected to provide results for Configurations E and F in its updated PA.

Path Forward:

DOE should present statistical results for Configurations E and F realizations separate from other Configuration similar to what is done for Configuration A and D in the probabilistic analysis. DOE should indicate how these configurations impact the peak dose within and beyond the 10,000 year compliance period. If the results of the Configurations indicate they are risk-significant, DOE should speak to the likelihood of these scenarios and consider aspects of these scenarios that may appropriately be incorporated in its base case evaluation (e.g., impacts of water table rise for Type IV tanks which exist in the zone of water table fluctuation at the FTF).

Reference

WSRC, 2008. "Performance Assessment for the F-Tank Farm at the Savannah River Site," SRS-REG-2007-00002, Revision 0, WSRC Site Regulatory Integration & Planning, Aiken, SC. June 27, 2008.

Clarifying Uncertainty/Sensitivity Analysis Comments

CC-UA-1

DOE should identify important parameters affecting dose from various pathways in its Revision 1 PA. For example, NRC staff noted that the dominant pathways in the deterministic versus probabilistic analysis differ by significant margins for the same radionuclides and exposure scenarios but other than the clear correlation between drinking water consumption and drinking water dose, other parameters that affect the relative importance of various pathways of exposure are not clear. Garden size was listed as an important parameter value in probabilistic sensitivity analysis but it is not clear how garden size affects the dose from the vegetable ingestion pathway based on the equations presented in the PA. In general, a more comprehensive discussion on how biosphere parameters affect peak dose and the appropriateness of parameter correlation (or lack thereof) is needed.

CC-UA-2

It is not clear how the relative concentrations between aquifers presented in Appendix F.2 of the Revision 1 PA support the assumed aquifer ratios presented in Table 5.6-6 of the PA. In some cases, Appendix F.2 tables indicate that the UTR-LZ concentrations are much higher than they are in the UTR-UZ. Relative concentrations between aquifers are demonstrated in Appendix F.2 to be radionuclide and tank-specific. Likewise, the GA concentrations appear to be much lower at the 100 m point than they are in the UTR (perhaps related to the fact that at 100 m the plume is either no longer in the UTR-UZ or not yet in the GA at this point; see comment RAI-FF-5 above). The basis for use of the 100 m concentrations and for the relative concentrations between aquifers presented in Table 5.6-6 based on nitrogen concentrations at this location is considered weak. Furthermore, the approach used in the probabilistic analysis to determine groundwater concentrations and dose confounds comparison of dose limits against exposures expected to occur at the point of maximum exposure wherever that point might exist vertically in the aquifer system below FTF. DOE should provide a stronger basis for the assumed ratios of groundwater concentrations.

CC-UA-3

DOE presents results for several high consequence realizations in the probabilistic uncertainty analysis that greatly exceed the compliance limit of 25 mrem/yr (0.25 mSv/yr) for Configurations A and D in the Revision 1 PA. The results of the realizations seem to fall around 300 mrem/yr (3 mSv/yr) for Configuration A and 10,000 mrem/yr (100 mSv/yr) for Configuration D within 10,000 years. It is not clear if additional realizations that differ markedly in the characteristics from those presented in the revised PA exist and if the actual peak dose limits from the realizations presented are capped based on the maximum value that occurs within 10,000 years (i.e., could higher doses be realized at longer time frames?).

- Please present additional high-risk realizations if they differ significantly from those presented in the PA.

- Provide dose versus time plots for the maximum realizations over timeframes that capture the peak dose.

- Explain why the maximum Pu dose increases orders of magnitude between Configuration A and D (from 300 mrem/yr [3 mSv/yr] to 12,000 mrem/yr [120 mSv/yr]). Is the increase in dose between Configurations due to capping of values in Configuration A (peak doses are not fully realized), due to basemat by-pass fraction, and/or attributable to some other phenomena?

CC-UA-4

Additional details regarding the impact of selection of solubility limiting phases, chemical transitions and inventory could be provided to elucidate system response as indicated in the results presented in Section 5.6 of the Revision 1 PA. Grout as reflected in contaminated zone chemical performance is arguably one of the most important barriers to waste release impacting potential compliance with performance objectives in 10 CFR Part 61, Subpart C. While uncertainty and sensitivity results presented in the PA certainly reinforce this conclusion, insufficient details are provided regarding second tier parameters or processes that may impact solubility transitions and waste release in the deterministic and probabilistic modeling. The following information would be helpful to elucidate factors important to system performance:

- Indicate if inventory plays a role in determining peak dose due to mass depletion prior to the final chemical transition in the base case analysis.

- Clarify if the selection of solubility limiting phase for Reducing or Oxidizing Phase II plays a role in determining the peak dose due to mass depletion prior to the final chemical transition.

- Clarify if the timing of chemical transition plays a large role in determining the peak dose due to mass depletion prior to the final chemical transition.

- Clarify if the peak dose is determined by an intermediate chemical transition (reduced or oxidized region II) for certain radionuclides under certain conditions based on selection of higher solubility limiting phases considered in the probabilistic analysis.

CC-UA-5

Clarify why the basemat fast flow case leads to earlier chemical transitions. See Figure 5.6-70 (Case 2 versus Case 6) in the Revision 1 PA.

Intruders

DOE performed an intruder analysis to demonstrate compliance with performance objectives related to direct intrusion into the disposal facility after institutional controls are assumed to fail at 100 years. The following comments address issues associated with transparency of intruder calculations. Additional biosphere comments are also provided.

To develop the following comments, staff reviewed the PA and supporting documents provided to NRC by letter dated April 2, 2010 (Gutmann, 2010). The staff's review criteria pertaining to the approach to intruder analysis are contained in Section 5 of NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007).

Table IT-1 Crosswalk of NRC Intruder Comments Resulting from Review of the Revision 0 PA to the New RAI Comments Based on NRC's Review of the Revision 1 PA

Old #	Subject	Adequate	Inadequate (Not Repeated)	Follow-up Comment ID	Note
IT-1	Sensitivity of intruder results			CC-PA-3 CC-IT-1 CC-IT-2 CC-IT-3	Response states that uncertainty/sensitivity analysis is provided for 61.41 evaluation and this should be sufficient. NRC notes that the intruder analysis considers drill cuttings, which is not evaluated in the 61.41 evaluation. Sensitivity to timing, tank, chronic exposure pathways, etc. was not included for drilling into a tank.
IT-2	Elimination of animal pathway in chronic intruder analysis from drill cuttings	X		CC-IT-3 CC-IT-4	Clarifies that the fodder is not contaminated with drill cuttings. The response is adequate but follow-up comments were developed.
IT-3	Lack of consideration of alternate configurations for intruder dose calculations		X		States that the sensitivity analysis for 61.41 is sufficient. NRC does not agree with the response but the comment will not be repeated.
IT-4	Calculation of drill cutting concentrations for intruder analysis	X			Soil concentrations were provided and calculations imply that the drill cuttings are not assumed to be diluted in a tilling depth.

RAI-IT-1

The basis for excluding environmental transfer factors from the uncertainty analysis is unclear.

Basis:

The DOE response indicated that uncertainty in transfer factors did not result in large changes to the total dose, therefore uncertainty in the transfer factors were not included in the probabilistic analysis.

The absolute changes to dose as a result of transfer factor uncertainty was small, however the relative changes were moderate to significant. The impact of transfer factor uncertainty should be part of the base case assessment.

Part of the reason for the distributions appears to be the derivation process documented in Lee and Coffield 2008 (WSRC-STI-2007-00004, Rev. 4). The process is not supported. DOE had derived transfer factors then updated them with a variety of sources, but primarily from PNNL-13421 (Staven et al. 2003). For many transfer factors, the updating was performed by calculating a geometric mean of the old and PNNL-13421 values. It is not apparent that there is a technical basis for this approach, and the approach can result in a significant underestimation of environmental pathway doses. For example, the soil to plant transfer factor for Ra (a key radionuclide) was reduced by a factor of 100 from the previous value using this approach. A footnote infers that the PNNL-13421 values are site-specific, but review of the reference indicates that the values are not site-specific but simply represent a different compilation of values.

Transfer factors operate on the concentrations derived at the end of the calculation, and can have very broad ranges. Many have very few observations. For the most part, the variance in observed values represents real world variability. Use of a geometric mean can result in a high likelihood of the actual value significantly exceeding the assumed value. Without actual site-specific measurements, transfer factors have to be selected conservatively.

Path Forward:

Provide technical basis for the expected value and distributions of transfer factors used in the analysis. If site-specific values are not available, it is recommended that the results are calculated with each set of transfer factors and presented individually, including results with the maximum and minimum observed values. The results should not be aggregated with a geometric mean transfer factor.

References

Staven, L. H., Rhoads, K., Napier, B. A., and D. L. Strenge, 2003. “A Compendium of Transfer Factors for Agricultural and Animal Products.” PNNL-13421, PNNL, Richland, WA. June 2003.

Lee, P. L. and T.W. Coffield, 2008. “Baseline Parameter Update for Human Health Input and Transfer Factors for Radiological Performance Assessments at the Savannah River Site.” WSRC-STI-2007-00004, Rev. 4. Savannah River National Laboratory, WSRC, Aiken, SC. June 13, 2008.

RAI-IT-2

The soil to plant transfer factors may be too low due to the elimination of the leafy plant component.

Basis:

Lee and Coffield 2008 (WSRC-STI-2007-00004, Rev. 4) uses soil to plant transfer factors for non-vegetative portions of food crops because local productivity of non-leafy vegetables is expected to be considerably greater than that of leafy vegetables (based on Hamby 1991). However, the transfer factors for leafy vegetables can be considerably larger than non-leafy vegetables for key radionuclides. For example, the reference most used as a source of transfer factors in the current analysis (Staven et al. 2003 – PNNL-13421) has a factor of 210 for leafy vegetables and a value of 0.24 for non-leafy vegetables for Tc. At a 13% leafy vegetable fraction, the vegetable pathway dose from Tc would be over 100 times larger with the leafy and non-leafy components calculated separately and then combined compared to assigning all vegetables as non-leafy. In addition, the Hamby 1991 reference may have underrepresented garden production data due to limited survey response.

Path Forward:

Include the leafy vegetable pathway explicitly in the plant pathway dose calculation. Consider using EPA or NRC references for garden productivity data.

References

Staven, L. H., Rhoads, K., Napier, B. A., and D. L. Strenge, 2003. “A Compendium of Transfer Factors for Agricultural and Animal Products.” PNNL-13421, PNNL, Richland, WA. June 2003.

Lee, P. L. and T.W. Coffield, 2008. “Baseline Parameter Update for Human Health Input and Transfer Factors for Radiological Performance Assessments at the Savannah River Site.” WSRC-STI-2007-00004, Rev. 4. Savannah River National Laboratory, WSRC, Aiken, SC. June 13, 2008.

RAI-IT-3

The drinking water ingestion rate of 337 L/yr is inconsistent with an average member of the critical group definition.

Basis:

The drinking water ingestion rate is calculated by taking the mean per capita total water ingestion of 1233 mL/day and multiplying by the 75% value from community water. However, this is weighting the critical group member’s consumption rate by the type of group the critical group member is in. Given the current site usage and definition of the receptor as a resident farmer, the drinking water consumption rate should be a minimum of 87% of the total water ingestion rate (subtract out the bottled water fraction). Consideration should also be given to adjusting the values for a receptor engaging in a more labor intensive lifestyles than average in a climate that is warmer than average.

Path Forward:

Modify the drinking water consumption rates to be consistent with the defined receptor and scenario.

Clarifying Intruder Comments

CC-IT-1

Page 800 of the Revision 1 PA presents sensitivity analysis results for intrusion into Tank 18. No basis is provided for why Tank 18 is a conservative tank or why the dose might not increase over time due to in-growth. This scenario is run at year 500. Sensitivity to (i) tank and (ii) timing of intrusion is needed. Alternatively, a stronger basis is needed to support the assumption that Tank 18 is expected to be the most limiting tank when considering the risk from inadvertent intrusion.

Additionally, only *acute* exposure to the inadvertent intruder is evaluated for the tank intrusion scenario. DOE should evaluate chronic exposure to contaminated drill cuttings brought to the surface in a tank intrusion event or provide a stronger basis for why this scenario is not evaluated.

For example, text on page 6-5 of the waste determination indicates that if a tank was encountered during drilling, the significant resistance afforded by the concrete and steel would result in termination of drilling operations (see also Section 4.2.4.2 of the PA). If this argument is used as a basis for lack of consideration of intrusion into a FTF tank to support the compliance demonstration or to justify lack of consideration of chronic exposures, then DOE should provide additional information to support the assumption that the cementitious materials and steel comprising the tank system, or other barriers to intrusion, will retain their strength and durability over the long time periods relied on for performance (e.g., 10,000 years) such that the tank system will continue to provide resistance to drilling or a recognizable waste form.

CC-IT-2

It is not apparent from the sensitivity analysis results that DOE considered parameters important to the dose from drill cuttings in the intruder analysis. Key parameters included just those parameters associated with the groundwater pathway. Due to the large scale of the sensitivity analysis figures (tens of thousands of mrem/yr or hundreds of mSv/yr) it appears that the contributions from the 1 m groundwater concentrations swamped the results for the drill cuttings portion of the dose to the intruder. Therefore, DOE should consider evaluating the drill cuttings dose independently as a sensitivity analysis endpoint to identify those parameters most important to the intrusion event (rather than those parameters most important to the dose associated with the 1 m well concentrations that are already informed by the groundwater sensitivity analysis).

Uncertainty analysis indicates that the garden size is important to dose. Based on review of the dose modeling equations presented in the PA, the correlation between garden size and dose is not clear. It appears that the garden size may affect whether the full vegetable consumption rates can be achieved for a given yield. Please clarify if the vegetable consumption rates based on site-specific data can be further reduced based on the yield and garden size parameters in the probabilistic analysis. If the rates can be reduced, justify why the consumption rates based on homegrown produce consumption rates should be further reduced.

It is also not clear how contaminated drill cuttings are expected to be distributed following the intrusion event. Clarify if the 0.2 and 0.02 dilution factors for the agricultural receptor and intruder were actually used in the analysis (see Table 4.6-5 on page 477 of the Revision 1 PA). If risk-significant, sensitivity analysis should also address the uncertainty in the distribution of contamination (e.g., area and depth or tilling depth).

CC-IT-3

DOE should perform sensitivity analysis to study the impact of inadvertent intrusion into various auxiliary equipment components. DOE currently assumes an intruder drills into a 3 inch transfer lines for its base case. The CTS, for example, may be more concentrated and lead to higher doses to an inadvertent intruder.

CC-IT-4

The Revision 1 PA, Table 4.2-39, (page 345) indicates the chronic intruder is quantitatively addressed for the pathway of drill cuttings-environmental uptake-garden fodder-livestock-ingestion. The response to a previous comment (IT-2) on the Revision 0 PA, the Revision 1 PA text and results indicate that this exposure pathway is not analyzed. DOE should confirm that this pathway was not evaluated and correct the inconsistency in the Revision 1 PA (e.g., correct Table 4.2-39.

CC-IT-5

Indicate why the external dose pathway for the chronic intruder is significantly lower than the vegetable ingestion dose from Cs-137. For example, explain the differences in methodology that led to the drastically different results for the dominant pathways associated with this radionuclide in the Revision 1 PA compared to the results from the INL PA for a similar well drilling scenario (DOE Idaho, 2003).

Reference

DOE Idaho, 2003. “Performance Assessment for the Tank Farm Facility at the Idaho National Laboratory Environmental and Engineering Laboratory,” DOE-ID-10966, Revision 1, Idaho Falls, Idaho. April 2003.

Site Stability

The following comments are all new comments developed based on review of the Revision 1 PA and associated references.

RAI-SS-1

Insufficient justification is provided in the PA for the long-term degraded mechanical properties of concrete and grout used in the structural behavior analysis.

Basis:

DOE addressed material degradation in Section 3.1 and 6.3 of T-CLC-F-00421 (DOE, 2007). In Section 3.1, DOE relied on the material degradation studies discussed in DOE (2006) and concluded that only marginal concrete degradation occurs over several thousand years. In addition, in Section 6.3, the 90-day compressive strength (1,800 psi) was used as a long-term degraded grout property for assessing structural integrity. However, DOE did not provide documents and data to support the assumption that the grout property will remain unchanged over the performance period.

Path Forward:

Provide a copy of DOE (2006) and additional data to support the long-term degraded material property for concrete and grout used in the PA analysis.

References

DOE, 2007. “Structural Assessment of F-Area Tank Farm After Final Closure.” T-CLC-F-00421. 2007.

DOE, 2006. “Low Activity Waste (LAW) Vault Structural Degradation Prediction.” T-CLC-E-00018, Revision 1. 2006.

RAI-SS-2

Inadequate basis is provided in the PA for precluding loss of integrity of the grout-filled tanks for annual probability of exceedance of 10^{-6} seismic event.

Basis:

In Section 3.2 of T-CLC-F-00421 (DOE, 2007), DOE discussed the integrity of the grout-filled tank and assumed that the tank will not crack under high seismic ground motion. DOE (2007) provided inadequate basis for (i) ground motion magnitude for 10^{-6} seismic event, and (ii) the assumption that the concrete tank will behave as rigid monolith when subjected to a 10^{-6} seismic event.

Ground motion levels for annual probability of exceedance of 10^{-6} were estimated to be 0.45 g for horizontal ground motion and 2.0 g for vertical ground motion. The ground motions were evaluated by extrapolating PC-3 and PC-4 site specific spectra presented in DOE (2006). The significant disparity between vertical and horizontal ground motions is contrary to the general understanding of seismic hazards in Central and Eastern United States Nuclear Power Plant (NPP) sites. The reference document (DOE, 2006) should be provided to support the horizontal ground motion evaluation.

The vertical ground motion has an extremely large acceleration of 2.0 g. However, DOE concluded that by inspection the grout monolith will not crack from these accelerations. DOE did not provide a technical basis for the assumption that the grout-filled tanks will behave as a rigid monolith. The grout-filled tank structure is likely to develop heterogeneity in the material property and may not act as a monolith because of different engineering properties of the grout and concrete. Additionally, long term degradation of strength and stiffness properties of the grout may impact the deformability of the tank structure.

DOE cited seismic analysis of the tanks for PC-3 and PC-4 seismic events to demonstrate that the lateral differential movement from soil-structure interaction effects is not sufficient to cause large shear forces (DOE, 2006). The discussion in DOE (2007) does not include the ground motion levels and the return period of PS-3 and PS-4 events for which the calculations were performed. There is also no discussion on how this analysis can be used to assess the stresses and deformations developed in the tanks for ground motions at an annual probability of exceedance of 10^{-6}. An analysis is needed to determine the seismically induced stresses in the tank structure caused by high seismic ground motion at a probability of exceedance of 10^{-6} considering the degraded properties of the grout and concrete.

Path Forward:

Provide a rationale for the estimated ground motion magnitudes for 10^{-6} seismic events and for the assumption the grouted tank will behave as a rigid monolith when subjected to 10^{-6} seismic events. This information is needed to demonstrate that the grout-filled tank will remain intact and meet the performance goals. In addition, provide a copy of the DOE (2006) report.

References

DOE, 2007. "Structural Assessment of F-Area Tank Farm After Final Closure." T-CLC-F-00421. 2007.

DOE, 2006. "Low Activity Waste (LAW) Vault Structural Degradation Prediction." T-CLC-E-00018, Revision 1. 2006.

RAI-SS-3

A long term stability analysis of the grout-filled tanks given the presence of large-scale Calcareous Zone voids and cavities in the Santee Formation beneath the FTF was not provided.

Basis:

Tanks 1–8 are located above subsurface voids located in the Santee Formation or the UTR-LZ aquifer (WSRC-TR-2007-00283). Similar or more severe voids and cavities are located below tanks 25–28 and 44–47 (WSRC-TR-2007-00283). Voids found within exploratory boreholes beneath tank locations were filled with grout to provide waste tank foundation support. Grout emplaced in these voids for the geotechnical purpose of ensuring site stability beneath tanks will degrade over geologic time.

Path Forward:

Provide a long term stability analysis of the grout-filled tanks considering the large-scale voids and cavities beneath the tanks.

Reference

Millings, M.R., and G.P. Flach, “Hydrogeologic Data Summary In Support of the F-Area Tank Farm (FTF) Performance Assessment (PA),” WSRC-TR-2007-00283, Washington Savannah River Company, Savannah River National Laboratory, Aiken, SC, July 2007.

Editorial Comments

Note: If any of these comments are more than editorial, NRC anticipates DOE will indicate as much in a comment response. Otherwise no response is expected.

E1 - Correct inconsistency in Zr isotope listed in Table 3.3-2 (Zr-93) versus Table 4.2-5 (Zr-99) of the Revision 1 PA.

E2 - Table 4.2-4 of the Revision 1 PA lists a subset of isotopes from each of four decay chains that are assumed to be initially present (complete decay chains are presented in Table 4.2-3). The PA text (page 252) states that the first member of each of the four decay chains is known to be present in FTF waste tanks. Yet, the first member of each of the four decay chains--Pu-241, Cm-248, U-238, and Cm-243—are not all listed in Table 4.2-4 as being initially present; Table 4.2-4 does not contain the first member of two of the four decay chains: Cm-248 and Cm-243. The table also does not contain a key risk driver for the FTF PA modeling, Pu-239, a daughter product of Cm-243. Correct inconsistencies between the text and table.

E3 - Table 4.2-5 "Radionuclides Used in *Initial* FTF Inventory Determination" of the Revision 1 PA lists several radionuclides in the four decay chains that are not listed as initially present in Table 4.2-4 "Isotopes from Four Decay Chains Present in Initial Inventory Used in FTF Modeling" (Cm-248, Pu-244, Pu-240, U-236, Th-232, Ra-228, Cm-243, and Pu-239). Of these radionuclides, six are contained in Table 3.3-2 listing actual initial inventories while two are not: Th-232 and Ra-228. Correct or clarify apparent inconsistencies between Tables 4.2-4 and 4.2-5.

E4 - Page 296 of the Revision 1 PA states that the Gordon aquifer is assumed to discharge equally from both sides of the UTR. This sentence should have stated the Upper Three Runs aquifer is assumed to discharge equally from both sides of the UTR.

E5 - Page 300 of the Revision 1 PA states that the PORFLOW GSA model was calibrated to head data. Non-unique solutions may result from use of head data only to calibrate a model. The model should have been calibrated to head, flow and discharge data. Please revise this statement for clarity.

E 6 - With regard to page 422, Table 4.4-6 of the Revision 1 PA, it is not clear what the material ids correspond to in the table. Suggest defining the materials listed in the table in a footnote to the table, or labeling the materials in a more descriptive manner in the table.

E7 - Page 618 of the Revision 1 PA states that Figure 5.2-4 of WSRC-TR-96-0399-Vol. 1 indicates the portion of an overall contaminant plume emanating from the FTF would fill the entire UTR-LZ thickness at 100m. Figure 5.2-4 in the *PA* actually shows this information.

E8 - Page 420 of the Revision 1 PA states "In general, chemical transitions for a material zone are based on infiltrate pore volumes for the same zone. For example, the volume of flow through the "basemat" zone is calculated and at the year when the calculated pore water volume equals transition volume (i.e., 371 volumes for transition to Oxidized Region II) documented in WSRC-STI-2007-00544, the materials in the "basemat" zone are modeled as having the properties associated with Oxidized Region II from that time frame onward."

However, the basemat should start at Oxidized Region II and should transition to Oxidized Region III and remain in this state from that time forward. Please correct.

E9 - Page 581 of the Revision 1 PA states that the drop panel thickness is considered when assigning the basemat thickness. Figures 3.2-11 and 3.2-12 are cited as showing the drop panel. The figures cited should actually be 3.2-13 and 3.2-14.

E10 - Page 805 of the Revision 1 PA indicates the investigation of UA realizations (Section 5.6.4.2) identified liner failure as potentially significant to peak doses within 20,000 years. The realizations discussed in Section 5.6.4.2 are for peak doses within 10,000 years not 20,000 years.

E11 - Page 807 of the Revision 1 PA indicates that while there is very little Ra-226 in the Type IV tanks, the Ra-226 is a daughter product of U-234 and Th-230, of which there is an appreciable quantity in the Type IV tanks. This statement should be qualified, as Th-230 is not expected to be present in appreciable quantity in the Type IV tanks.