Transition from Consultation to Monitoring—NRC's Increasingly Focused Review of Factors Important to F-Area Tank Farm Facility Performance – 13153

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ABSTRACT

In consultation with the NRC, DOE issued a waste determination for the F-Area Tank Farm (FTF) facility in March 2012. The FTF consists of 22 underground tanks, each 2.8 to 4.9 million liters in capacity, used to store liquid high-level waste generated as a result of spent fuel reprocessing. The waste determination concluded stabilized waste residuals and associated tanks and auxiliary components at the time of closure are not high-level and can be disposed of as LLW. Prior to issuance of the final waste determination, during the consultation phase, NRC staff reviewed and provided comments on DOE's revision 0 and revision 1 FTF PAs that supported the waste determination and produced a technical evaluation report documenting the results of its multi-year review in October 2011. Following issuance of the waste determination, NRC began to monitor DOE disposal actions to assess compliance with the performance objectives in 10 CFR Part 61, Subpart C. To facilitate its monitoring responsibilities, NRC developed a plan to monitor DOE disposal actions. NRC staff was challenged in developing a focused monitoring plan to ensure limited resources are spent in the most cost-effective manner practical. To address this challenge, NRC prioritized monitoring areas and factors in terms of risk significance and timing. This prioritization was informed by NRC staff's review of DOE's PA documentation, independent probabilistic modeling conducted by NRC staff, and NRC-sponsored research conducted by the Center for Nuclear Waste Regulatory Analyses in San Antonio, TX.

INTRODUCTION

DOE issued a waste determination for the F-Area Tank Farm Facility (FTF) in March 2012 [1] that concluded that stabilized waste residuals in FTF tanks and auxiliary components as well as the tanks and auxiliary components themselves could meet NDAA criteria for waste incidental to reprocessing (WIR) at the time of closure and as such could be disposed of *in-situ* as LLW. Following issuance of the FTF waste determination and in accordance with the NDAA, NRC staff began to monitor DOE disposal actions to assess compliance with the performance objectives in 10 CFR Part 61, Subpart C. The performance objectives included in the regulations in 10 CFR Part 61, Subpart C are: (i) general requirement (§61.40), (ii) protection of the general population from releases of radioactivity (§61.41), (iii) protection of individuals against inadvertent intrusion (§61.42), (iv) protection of individuals during operations (§61.43), and (v) stability of the disposal site after closure (§61.44).

DOE's issuance of the FTF waste determination was supported by a multi-year consultation with the NRC that began in February 2007 with a series of approximately nine scoping meetings that occurred

over the course of a year through February 2008. These scoping meetings were held between DOE, NRC, EPA, and South Carolina Department of Health and Environmental Control (SC DHEC) with the latter two having regulatory authority over DOE closure actions under the Pollution Control Act (PCA), RCRA and CERCLA. Technical topics discussed at these scoping meetings included: (i) biosphere parameters (e.g., exposure pathways, bioaccumulation factors, consumption rates, dose conversion factors), (ii) closure cap, (iii) inventory including radionuclide screening, (iv) far-field and (v) near-field modeling (e.g., vadose zone properties, waste tank design, cement/grout properties, waste release, tank liner life estimates), (vi) general performance assessment issues (e.g., model codes, model integration), and (vii) uncertainty and sensitivity analysis including probabilistic model development. In NRC staff's estimation, the most significant improvement that DOE made to the development of the PA based on the scoping process was the development of a probabilistic model to evaluate uncertainty in PA model predictions. Before then, DOE had relied solely on deterministic models to support WIR decision-making with limited ability to perform uncertainty analysis. For complex systems, NRC considers probabilistic models to have a distinct advantage over deterministic models because probabilistic models are better equipped to evaluate a wider range of the expected parameter space and identify important model sensitivities that may be more difficult to discern using deterministic approaches.

Following scoping, DOE submitted Revision 0 of the FTF performance assessment (PA) in June 2008 [2]. NRC staff reviewed the PA and submitted 90 comments on the revision 0 PA in January 2009 [3]. DOE considered NRC and other stakeholder comments in finalizing revision 1 to the FTF PA in March 2010 [4]. NRC staff reviewed the revision 1 PA and issued 94 requests for additional information (RAI) or clarifying comments in December 2010 [5]. DOE made notable improvements to the inventory and uncertainty/sensitivity sections in the revision 1 PA. DOE revised the inventory estimates used for PA calculations generally upwards in the revision 1 PA to account for uncertainty in waste retrieval effectiveness and uncertainty in waste tank concentrations. DOE also revised the probabilistic model for the revision 1 PA resulting in an improved sensitivity analysis compared to initial studies.

The total number of revision 1 PA review comments made by NRC staff increased for some technical areas and decreased for others. For example, many engineered closure cap comments were deferred until the construction phase. Several new comments on site stability and far-field were developed to address potential issues associated with calcareous zone dissolution, a site feature that NRC staff identified during review of the revision 1 PA. These calcareous zones (or "soft zones") located in the lower Upper Three Runs aquifer have undergone variable dissolution. After discovery of these soft zones during construction of the FTF in the 1950s, DOE filled the zones with grout to provide structural stability. NRC staff is concerned that the zones might have an effect on contaminant flow and transport as well as impact overall site stability. NRC staff also developed a number of far-field comments related to the benchmarking process due to concerns about potentially excessive dispersion in the deterministic models and due to incongruous results between DOE's probabilistic and deterministic models.

Although NRC staff identified new issues in the revision 1 PA review, the total number of more *risk-significant* comments referred to as RAIs decreased significantly between the revision 0 and revision 1 reviews due to NRC staff's increased familiarity with key aspects of facility performance (see Fig. 1). During most of the scoping process, NRC staff reviewed DOE sub-models and parameters in isolation as they were developed. NRC staff did not have the benefit of review of an integrated PA model to better

understand DOE reliance on individual sub-models and parameters. This made it difficult for NRC to assess the risk-significance of some of its comments. Additionally, without the benefit of PA modeling results for most of the scoping process and without its own independent model, NRC staff ran the risk of not focusing enough attention on what might ultimately be a key aspect of facility performance. For example, PA results may have indicated the importance of release and transport assumptions for a handful of radionuclides while NRC staff provided comments on development of solubility and K_ds more generally for an exhaustive list of radionuclides. NRC recognized this potential problem at the beginning of scoping and made it clear that it was only providing high-level feedback to DOE during development of its PA model and that it reserved the right to request additional information after it reviewed the integrated PA in its entirety. Because NRC staff was only providing general comments during scoping, no attempt was made at that time to differentiate more or less risk-significant comments. Even with the benefit of DOE's PA results, transparency and model construction issues affecting the probabilistic sensitivity analysis made it difficult for NRC staff to fully understand the importance of various components of DOE's PA model during the revision 0 review. Through its continued review of DOE PA models and development of its own independent modeling and research, NRC staff has gained a better understanding of those factors most important to FTF performance. Risk insights gained during the consultation phase are reflected in NRC's prioritization of factors important to monitoring as presented in NRC staff's monitoring plan [6].

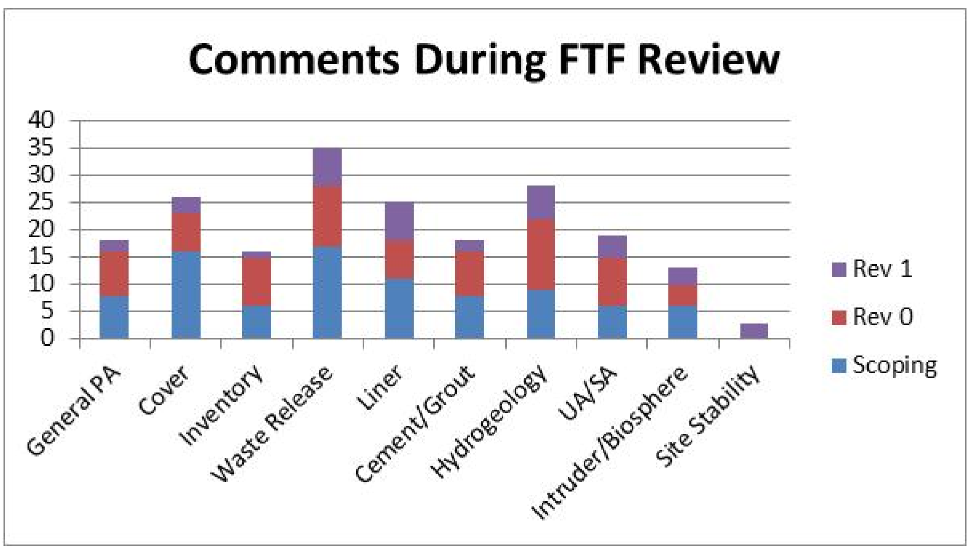

Fig. 1. Number of More Risk-Significant Comments or RAIs Made on DOE PA Documentation during Three Consultation Phases

DISCUSSION

To help rank and prioritize review comments and focus limited NRC resources to monitor DOE disposal actions to assess compliance with the performance objectives, NRC staff has participated in a number of risk-informing activities. These activities include DOE PA model reviews, independent model development, and NRC-funded research. NRC staff has staggered these activities over time and has performed them in an iterative manner as information is collected and as risk insights are developed. NRC staff will continue to perform these activities and revise experimental approaches and refine models

as new information is obtained. For example, DOE plans to perform special analyses to provide final risk estimates following sampling and analysis of tank residuals as each tank is cleaned and closed. Final inventory estimates are a key modeling uncertainty that can be readily reduced to update risk estimates for the site as tank farm closure progresses. NRC staff will also incorporate this information in its independent PA models as the information is developed.

The following sections describe example results or significant work products from NRC staff's (i) review of DOE Models, (ii) independent modeling, and (iii) independent research. The information gathered from these risk-informing activities was considered in development and prioritization of monitoring factors in NRC staff's monitoring plan [6] discussed in more detail in the "Overall Results" section.

Review of DOE Models

To risk-inform its reviews and monitoring efforts, NRC staff first evaluated DOE's primary PA models. DOE's primary deterministic near- and far-field models were created using the PORFLOW® computer code. Other PA models DOE used to provide inputs to the PORFLOW® [7] model include a HELP [8] model that is used to provide boundary conditions to the PORFLOW® near-field model and Geochemist's Workbench® simulations to calculate chemical transition times and changing solubility of key radionuclides over time. NRC staff is reviewing DOE's geochemical models and conducting a sensitivity analysis to further evaluate the effects of variability and uncertainty. To better understand barrier performance in the reference case, NRC staff also modified DOE's PORFLOW® files to create additional observation points or intermediate outputs from which it could better track releases from the tanks and peak concentrations of key radionuclides along FTF flow paths to various points of compliance. NRC staff's review of DOE's deterministic PORFLOW® models was beneficial because it enabled NRC staff to better understand the importance of various barriers in DOE's reference case.

NRC staff's review of DOE's PA documentation revealed that DOE expects three radionuclides will dominate the potential peak dose when considering longer periods of performance (Tc-99, Pu-239, and Np-237). NRC staff created additional observation points and intermediate results in DOE's PORFLOW® input files to help track the release and peak concentrations of each of these key radionuclides along their flow paths from FTF source zones, through concrete basemats, the vadose and saturated zones to the 100-m compliance point. The results of these evaluations are presented in Table I. In Table I, the "total barrier performance needed" row was calculated by assuming that the entire FTF tank inventory is located in the pore water of the contaminated zone. While this is virtually impossible, assuming that the total inventory is available to a potential receptor provides a baseline from which to evaluate the contributions of various barriers to reduce risk and to gauge the relative residual risk associated with each key radionuclide listed based on the (i) inventory and (ii) groundwater pathway dose conversion factor for each radionuclide. A value of "6" for Tc-99 in the first row corresponds to a factor of 10^6 or 1,000,000. The factor represents the reduction of the concentration in the waste zone needed to produce a groundwater concentration at the point of compliance equivalent to 0.25 mSv/yr (25 mrem/yr) total effective dose equivalent based on DOE biosphere modeling in the FTF PA for the baseline. In addition to providing information on barrier performance, Table I also provides NRC staff's perception of the level of support for the performance of various barriers (i.e., the table indicates "potentially optimistic" performance with yellow shading) and areas where uncertainties could be reduced (i.e., the

table indicates barriers for which additional information collection is expected to be “most tractable” with blue shading).

Table I. Relative Order of Magnitude Risk and Contributions of FTF Barriers to Reducing Risk for Three Key Radionuclides (Tc-99, Pu-239, and Np-237)*

		Tc-99	Pu-239	Np-237	Notes
1	Total Barrier Performance Needed (Function of Inventory)†	6** (Type I)	9 (Type IV, Tank 18)	6** (Type I)	Factor reduction in concentration needed to meet the §61.41 dose standard. The tank/type producing the highest dose for each key radionuclide is provided in parentheses.
			Engineered System		
2a	Solubility Control	0**	2**	1 to 2**	Final solubility
2b		(9 to 11)^	(9 to 11)^	(5 to 6)	Initial solubility
3	Basemat Attenuation (Sorption)	<1	2^	2^	Very important for Pu and Np. Can compensate for solubility.
4	Near-Field Diffusion or Dispersion‡	2^	1^	1^	Additional reduction in concentration due to upward diffusion into tank grout, large cell size, or dispersion.
			Natural System		
5	Aquifer Dilution	1	1	1	Based on simple aquifer mixing model; comparison of concentrations between vadose zone, source and saturated zones. Pu sorption can compensate for other barrier underperformance.
6	Sorption	<<1	1**	<<1	
7	Additional Dispersion to POC	1-2^	1^	1^	
8	Total Barrier Performance	5	8	6 to 7	Sum of rows 2a, 3-7.
9	Calculated Safety Margin	-1	-1	0 to 1	Difference Between Row 8 and Row 1.

*All values in the table are approximate (order of magnitude); values are only intended to provide relative information on the contributions of various barriers in DOE’s FTF PA and are not expected to be exact. Many of the values for the various barriers were estimated based on tracking the concentrations of the three key radionuclides from the contaminated zone to the point of compliance in DOE’s PORFLOW® models for the tank/type listed in Row 1.

†The “total barrier performance needed” is calculated by assuming that the entire FTF tank inventory is located in the pore water of the contaminated zone. While virtually impossible, assuming that the total inventory is available to a potential receptor is necessary to provide a starting point from which to evaluate the contributions of various barriers to reducing risk and to gauge the relative residual risk associated with each key radionuclide listed based on inventory and groundwater pathway dose conversion factor (measure of risk) of each radionuclide. The contaminated zone is assumed to be 0.25 cm thick with a porosity of 0.27.

‡Dispersion is used in a broad sense to describe diffusion, numerical, and physical dispersion in DOE’s PA models. Because Tc-99 is ultimately assumed to be highly soluble and mobile in DOE’s PA model, almost all of the attenuation of Tc-99 is due to dilution and dispersion. No solubility control is assumed for Tc-99 upon transition to the final chemical state.

**Most Tractable

^Potentially Optimistic

As a result of this analysis, NRC staff noted significant dispersion in DOE’s PA models (e.g., ultimately most of the attenuation of Tc-99 is due to dilution and dispersion because Tc-99 is not assumed to be solubility controlled over longer time periods, and when oxidized, it is not significantly attenuated by cementitious and natural materials). NRC staff also noted that DOE’s GoldSim® probabilistic modeling results show significantly higher peak doses from Tc-99 and Pu-239 compared to the deterministic model. As part of PA maintenance, NRC staff recommended that DOE provide additional support for the level of dispersion in its models. NRC staff’s review of DOE’s PA models also revealed strong reliance on initial solubility control for key radionuclides and tank basemats to provide significant attenuation of Pu-239 and Np-237 releases from the tanks. Therefore, NRC staff developed monitoring factors related to

solubility control and basemat sorption in the FTF monitoring plan [6] and assigned them a high priority ranking.

Although NRC staff's review of DOE's models was beneficial in the sense that the staff better understood those key barriers relied on for performance in DOE's reference case, NRC's initial analysis provides limited information regarding the relationship between barriers and the ability of individual barriers to act alone (or in combination with other barriers) to reduce risk when other barriers fail. Additionally, NRC's initial analysis of DOE's deterministic models did not show the impact of various combinations of under- and over-performance of barriers relative to DOE's reference case assumptions. This is important because NRC staff thinks that the level of performance assumed in DOE's reference case for several key barriers is not fully supported. Therefore, NRC staff performed additional analyses to study the impact of varying levels of performance of individual barriers in DOE's deterministic model.

As an example of barrier analysis, Table II provides a list of three key barriers in DOE's FTF PA: (i) solubility or chemical control, (ii) basemat sorption, and (iii) natural system sorption. Table III provides a description of five barrier analysis cases. For simplicity, the analysis assumes two or three levels of performance for each barrier. Fig. 2 shows an example barrier analysis for Pu-239 in Tank 18, one of the more risk-significant radionuclides/tanks at FTF based on current inventory information. Doses reported in Fig. 2 are relative to the maximum dose reported for Case 5. Case 5 represents a scenario where all three barriers are "off" or assumed to be severely degraded. The results of the analysis show what Table I is unable to show - that the basemat can compensate for under-performance of solubility control and natural system sorption can compensate for under-performance of the concrete basemats or solubility control as evidenced by the similar dose results reported for cases 2 through 4. This is true because when solubility control is low or moderately low, the basemat controls release from the tanks and so the peak dose is not very sensitive to solubility limits over a large range. Also, when the basemat and the natural system are both performing as well as assumed in the reference case, the potential contributions of the natural system in reducing peak dose in Table I are masked because only the timing, and not the magnitude of the peak dose, is affected when both barriers are performing as expected. If the basemat is assumed to fail, the importance of natural system sorption is dominant in reducing the magnitude of the peak dose (sorption in the natural system can compensate for almost all of the basemat performance reported in Table I if the basemat does not perform as well as assumed in the basecase). Cases 2 and 3 also illustrate that the potential dose could be higher even with a lower solubility when the transition to higher solubility occurs earlier. DOE assumes that the chemical transition to high solubility occurs at around 35,000 years in its basecase. At 35,000 years, a significant fraction of the Pu-239 inventory has decayed (the half-life of Pu-239 is 24,000 years). When the solubility transitions to higher values significantly earlier in time (around 10,000 years), more Pu-239 inventory is available for release to offset any decrease due to a lower solubility.

TABLE II. Barrier Effectiveness Levels

Barriers	**States (Worst to Best)**		
Solubility Control	Low Solubility Control (Very High Solubility Limit)	Moderate Solubility Control (Moderate Solubility Limit)	High Solubility Control (Low Solubility Limit)
Basemat Sorption	None (No sorption or by-Pass)	Moderate to High Sorption (High K_d)	

Natural System Sorption	Low Sorption (Low K_d)	Moderate Sorption	High Sorption (High K_d)

Table III. Barrier Analysis Cases

	Solubility Control	Basemat Sorption	Natural System Sorption
Case 1 None Off (All On)	High	Moderate to High	High
Case 2 Solubility Partially Off **Solubility Increases Earlier	Moderate	Moderate to High	Moderate
Case 3 Solubility Control Off	Low	Moderate to High	Moderate
Case 4 Solubility Control Partially Off, Basemat Off (By-Pass)	Moderate	None	Moderate
Case 5 All Off (None On)	Low	None	Low

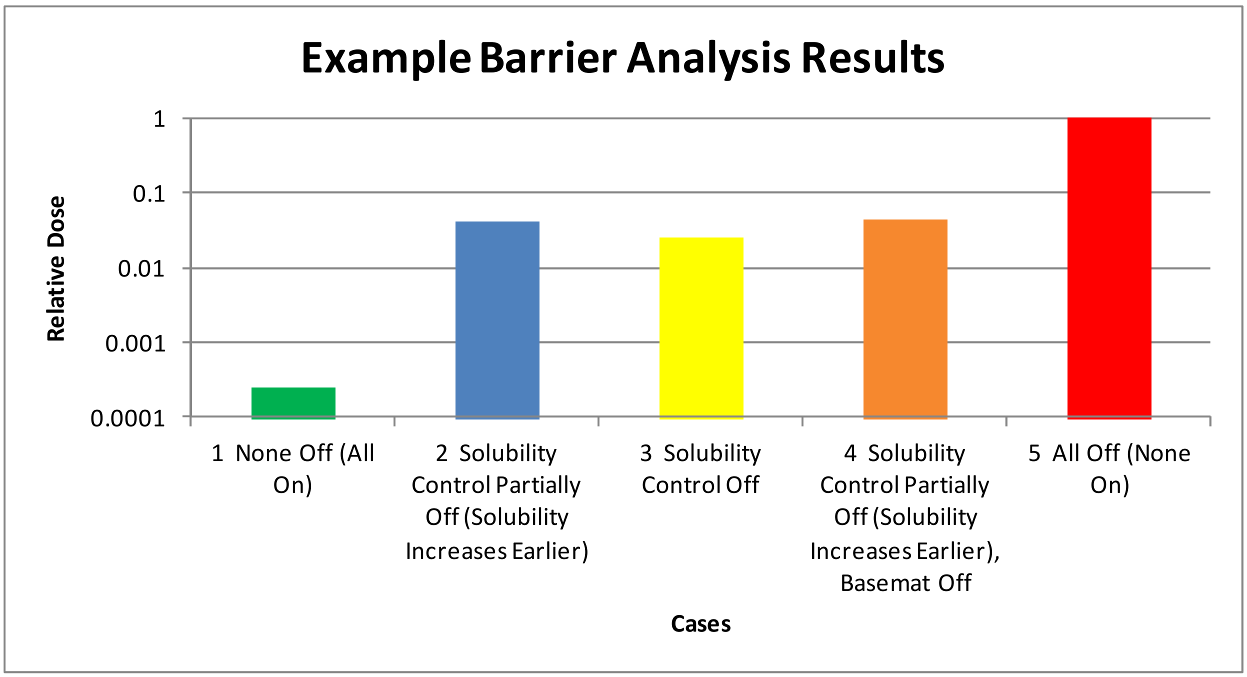

Fig. 2. Peak Pu-239 Dose for Tank 18 for Various Assumed Levels of Performance of FTF Barriers.

NRC staff also reviewed DOE models to obtain a better understanding of the amount of attenuation occurring between the source and the 1- and 100-m compliance points and potential cumulative impacts associated with releases from multiple tanks. Fig. 3 shows example output for relatively mobile Tc-99 released from Type I tanks and for relatively immobile Pu-239 released from Tank 18. DOE assumes that Type I tanks all fail at the same time in their deterministic model even though the steel liners may reasonably be expected to fail at different times. The Type I tank doses are dominated by Tc-99 releases in DOE's PA. The impact of assuming all eight, Type I tanks fail at the same time is an approximately 3-

5 times higher Tc-99 dose than if a single Type I tank failed, depending on the location of the single tank. NRC staff also observed dilution factors between 15 and 40 from the source to the 1-m boundary and dilution factors between 1.3 and 3 from the 1-m to the 100-m boundaries for Tc-99 from Type I tanks. This represents a total dilution factor between 40 and 60 from the source to the 100-m compliance boundary. Dilution is a function of Type I tank location and the number (and volume) of cells where flux to the saturated zone is loaded[1]. The results forTank 18 show that the attenuation factor (attenuation due to dilution and sorption) for Pu-239 is approximately a fator of 5 from the source to the 1-m boundary and 10 from the 1-m boundary to the 100-m boundary for a total factor of 50 lower concentration from the source to the 100-m boundary. The information gleaned from review of DOE's far-field model helps NRC staff understand natural system performance and cumulative impacts of multiple sources. NRC staff uses this type of information to construct its independent models discussed next.

Development of Independent NRC Models

NRC staff developed its own independent probabilistic model using the GoldSim® [9] modeling platform to independently assess DOE's PA modeling results and to identify those parameters and processes most important to FTF performance. NRC staff's model contains the most recent inventory estimates for each tank and significant auxiliary component provided in DOE's revision 1 PA [4] and Tanks 18 and 19 special analysis [10]. NRC's model allows staff to specify a separate wall inventory to assess risk of potentially unconditioned[2] key radionuclide release from FTF tanks. The staff's model also contains design specifications for the three different tank types present in the FTF, as well as tank-specific information important to contaminant transport such as vadose zone thickness and distance to the 100 m point of compliance. The staff is able to select any individual tank or a hypothetical tank that reflects the maximum inventory of each radionuclide from any FTF tank. The model incorporates BDose™ [11] as a sub-model to estimate potential doses in the biosphere to members of the public. Fig. 4 shows the tank inventory input screen that is linked to a Microsoft Access database where changes to model parameters are recorded and historical values are archived.

NRC's independent GoldSim® model allows staff to independently assess results of DOE's PA analyses. It also enables NRC to perform independent sensitivity analysis and alternative scenario analysis to evaluate potential vulnerabilities in FTF performance. When differences between DOE and NRC models exist, NRC staff evaluates the cause of the discrepancies and makes adjustments to its own model or recommends adjustments to DOE models. NRC staff is able to more efficiently perform these types of sensitivity and "what if" simulations through use of a probabilistic model rather than performing more resource-intensive deterministic simulations using DOE's PORFLOW® models. It is important to note that it is not NRC's intent to provide dose predictions. Rather, NRC staff uses various tools during its

[1] The flux assumed to be exiting the vadose zone based on near-field modeling for a representative Type I tank is assumed to be the same for each Type I tank. However, this flux is distributed to a different number (and volume) of cells located underneath each Type I tank. For example, some tanks footprints fall below one far-field model cell, while other tank footprints fall below two far-field model cells.

[2] DOE assumes that infiltrating groundwater is conditioned through its interaction with reducing tank grout that serves to increase pH and decrease Eh, thereby creating a chemical environment that generally limits key radionuclide solubility and release. If groundwater were not conditioned through its interaction with reducing tank grout, then key radionuclide release may be much higher and occur much earlier than assumed in DOE's reference case.

reviews to focus on more risk-significant issues, ask better questions, and to make better recommendations with the goal of improving overall designs and decision-making.

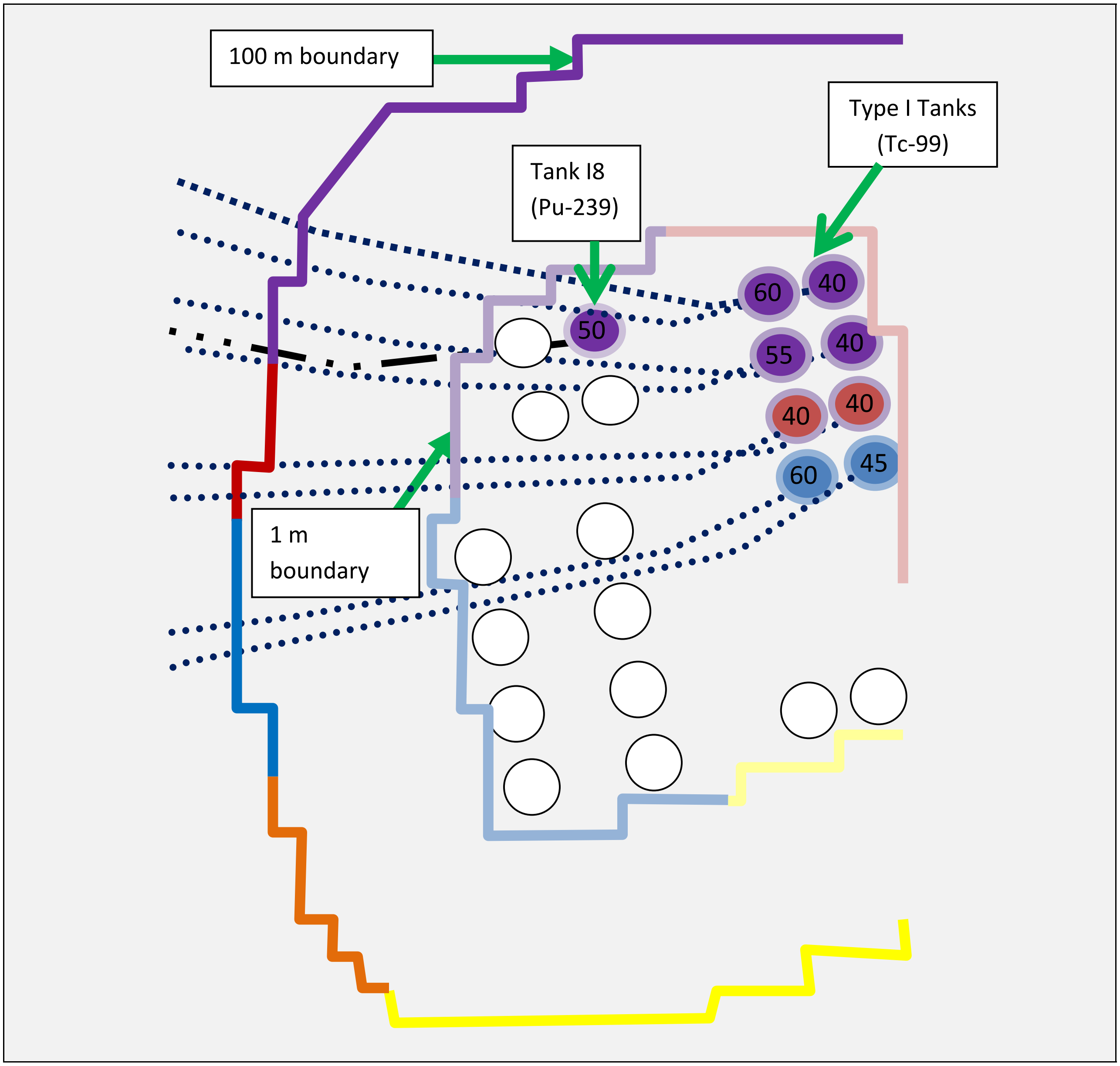

Fig. 3. Dilution/Attenuation Factors From Various FTF Sources to Compliance Points (Adapted from DOE, 2008, Figure 5.2-5). Color coding of tanks illustrates the 1-m and 100-m sectors to which the tank contributes most.

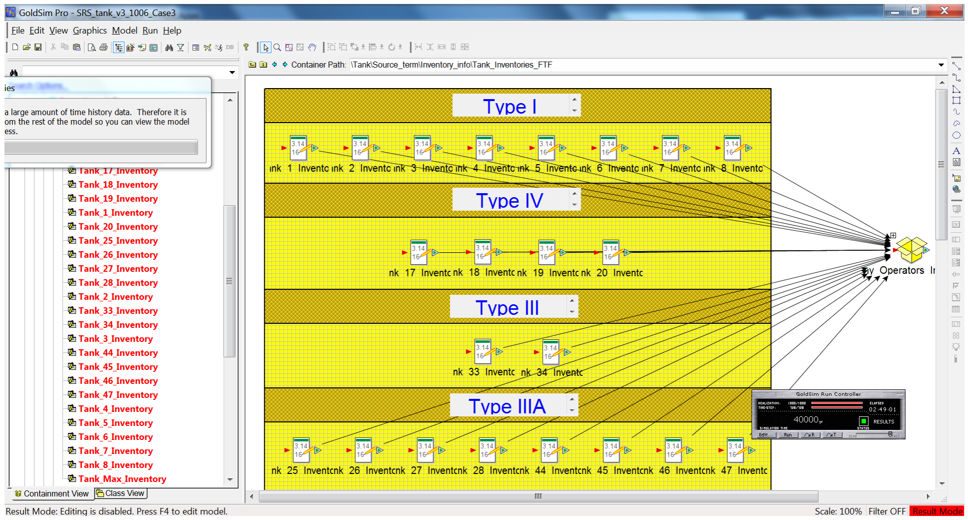

Fig. 4. Tank Inventory Input Screen in NRC Staff's Independent Probabilistic Model

Independent Research

NRC staff has also initiated several independent research projects under contract with the Center for Nuclear Waste Regulatory Analyses (CNWRA) over the past several years. These projects have included a literature review and assessment of factors important to high-level waste tank performance [12], an experimental study of the prevalence of preferential or by-passing flow pathways through and around stabilized high-level waste tanks and their impact on performance of the tanks [13-16], and experiments to study the leachability of radionuclides from cementitious grout waste forms [17].

Fig. 5 shows two experiments conducted in the last few years at the CNWRA in San Antonio, TX. The information gleaned from these experiments has been helpful to NRC staff in raising risk-significant concerns and providing important information to support its consultation and monitoring activities under NDAA. Table IV provides a listing of recent CNWRA activities performed to support NRC's WIR reviews. NRC is interested in working with DOE to perform waste release experiments to study the solubility of key radionuclides in actual SRS tank residual waste for different end-member chemical environments (e.g., unconditioned and fully conditioned groundwater).

Overall Results

The results of these analyses show that factors important to performance include residual waste inventory, waste release parameters (e.g., chemical transition times and solubility limiting phases/limits), hydraulic and chemical performance of cementitious materials (e.g., groundwater conditioning, shrinkage and cracking, basemat K_ds), and natural system performance (e.g., soil K_ds). In most cases, inventory is linearly related to dose and is, therefore, important to the PA results. Chemical transition times dictate the time at which key radionuclide solubility increases to risk-significant levels. If DOE relies on the timing of peak dose (i.e., potential doses are higher than the performance objectives but do not occur until after the period of performance), then chemical transition times may become important to the compliance demonstration. For some key radionuclides, solubility control can be the most effective barrier limiting the potential dose (see negligible Fig. 2 dose when solubility control is most effective). Conditioning of

infiltrating groundwater by the reducing tank grout is important because it keeps key radionuclide solubility low. Groundwater conditioning is dependent on the extent to which water interacts with the reducing grout. The extent of interaction is dependent on whether flow occurs through the grout matrix or whether flow by-passes most of the tank grout through fractures or cracks. Therefore, shrinkage, that may create gaps between steel components and tank grout, and cracking that may create pathways for fluid to flow through a small portion of the tank grout or around tank grout, are important to the compliance demonstration. Fig. 2 also illustrates the importance of basemat or natural system sorption in mitigating the potential dose associated with Pu-239. Table I shows basemat sorption is also important to Np-237. Furthermore, because Np-237 is not expected to sorb appreciably in the natural environment, solubility control and basemat sorption are expected to be the only significant barriers limiting Np-237 dose. Table V provides a complete list of NRC staff's monitoring factors and associated priority.

CONCLUSIONS

As modeling results have been generated and analyzed, NRC staff has increasingly focused its review of DOE PA documentation for the FTF. Following completion of the FTF TER in October 2011 [18], NRC staff developed a plan to facilitate monitoring of DOE disposal actions to assess compliance with the performance objectives in 10 CFR Part 61, Subpart C [6]. NRC staff strove to develop a focused monitoring plan to ensure that resources are spent in the most cost-effective manner practical. To meet this challenge, NRC prioritized monitoring factors in terms of risk-significance and timing. This prioritization was informed by NRC staff's review of DOE's PA documentation, independent modeling, and NRC-sponsored research. The results of these analyses show that factors important to performance include residual waste inventory, waste release parameters (e.g., chemical transition times and solubility limiting phases/limits), hydraulic and chemical performance of cementitious materials (e.g., groundwater conditioning, shrinkage and cracking, basemat K_ds), and natural system performance (e.g., soil K_ds). Development and prioritization of monitoring factors to focus on the most risk-significant aspects of facility performance is more effectively accomplished through open communication and a collaborative process involving key stakeholders. NRC staff will continue to work with its Federal and State partners, as well as members of the public, to fulfill its responsibilities under the NDAA to monitor DOE disposal actions at the FTF as tank farm closure progresses.

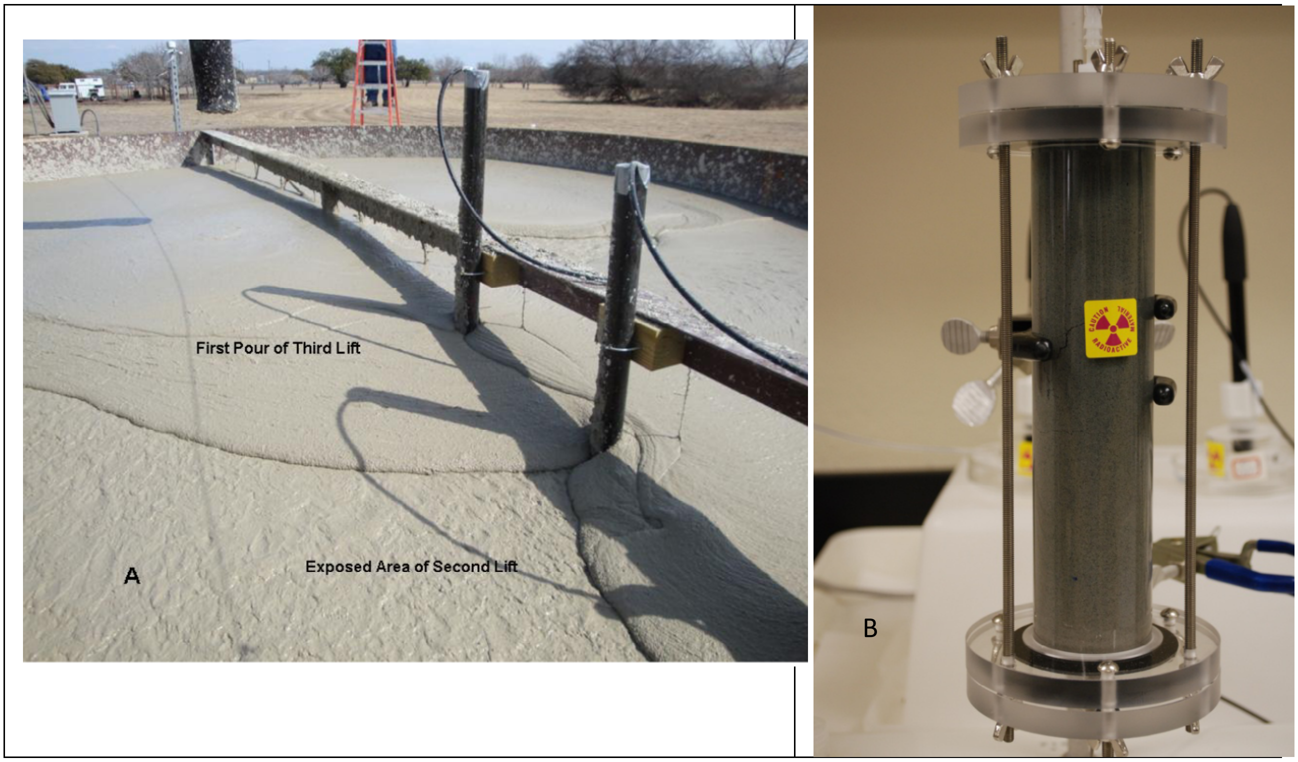

Fig. 5 (A) Grout Monolith and (B) Column Experiments Conducted at CNWRA in San Antonio, TX, with Cementitious Grout Materials proposed for WIR applications.

TABLE IV. CNWRA Research Initiatives and Work Products

Research Initiatives and Work Product	Description
Description of Methodology for Biosphere Dose Model BDose™ ML083190826 Simpkins, A.A., et al., November 2008	A biosphere model created in GoldSim® that calculates potential dose to members of the public and inadvertent intruders from acute and chronic exposure through various groundwater related pathways or contact with waste.
Review of Literature and Assessment of Factors Relevant to Performance of Grouted Systems for Radioactive Waste Disposal ML090980428 Pabalan, R.T., et al., April 2009	Literature review, modeling, and analyses of cementitious systems that provides information on the following: • Cementitious material degradation • Assessment of effects of preferential or by-passing pathways on waste release • Radionuclide release mechanisms • Solubility of key radionuclides • Hydraulic properties
Mesoscale Grout Monolith Experiments: Results and Recommendations ML092110510 Walter, G.R., et al., July 2009	Documents construction and initial test results (e.g., gas permeability and temperature) of mesoscale grout monolith experiments (e.g., 55-gal drums and a 30° arc, 3-m radius specimen) using various grout formulations proposed by DOE.
Estimated Longevity of Reducing Environments in Grouted Systems for Radioactive Waste Disposal ML101160513 Painter, S.L. and R.T. Pabalan, October 2009	Estimates how long reducing conditions could persist in near-surface slag-bearing grouted systems for radioactive waste disposal using numerical modeling to represent oxygen transport in fractures and porous grout. Evaluates a range of hydrological conditions, fracturing scenarios, and grout parameter values.
Intermediate Scale Grout Monolith and Additional Mesoscale Grout Monolith Experiments: Results and Recommendations ML1026404481 Walter, G.R., et al., September 2010	Documents construction and testing of a 6.1 m diameter, 0.9 meter deep grout monolith prepared with a sand-based, next-generation SRS-like reducing grout. Additional mesoscale grout drums were constructed. Gas injection re-testing results of drums constructed in 2009 were reported.
Bonding and Cracking Behavior and Related Properties of Cementitious Grout in an Intermediate-Scale Grout Monolith ML112700059 Dinwiddie, C.L., et al., September 2011	Evaluates crack development and grout–steel tank liner bonding in a 6.1 m diameter 0.9 meter deep grout monolith. An extensive crack network developed in the specimen that actively conducted water from boreholes to the perimeter. Bonding between the grout and tank wall was generally poor.
Fiscal Year 2012 Meso and Intermediate Scale Grout Monolith Test Bed Experiments: Results and Recommendations ML12251A305 Dinwiddie, C.L., et al., August 2012	Re-tests tank-grout specimens to evaluate the temporal evolution of annulus apertures and bulk permeability, observing general increases in these properties with time. Preferential flow through annuli, cracks and shrinkage gaps between grout lifts dominate fluid flow.
Revised Final Progress Report: Experimental Study of Contaminant Release From Reducing Grout ML12089A319 Pabalan, R.T., G.W. Alexander, D.J. Waiting, March 2012	Provides information on technetium, uranium, and selenium leach rates from a reducing cementitious waste form, the rate and extent of groundwater conditioning of the grout, and diffusion coefficients.

TABLE V. NRC Prioritization of Monitoring Factors That Support 10 CFR 61.41 and 61.42

Monitoring Areas (MA)				
MA 1 Inventory	**MA 2 Waste Release**	**MA 3 Cementitious Material Performance**	**MA 4 Natural System Performance**	**MA 5 Closure Cap**
1.1—Final Inventory and Risk Estimates†	2.1—Solubility-Limiting Phases/Limits and Validation§	3.1—Cement Vault Performance (As It Impacts Steel Liner Corrosion)‡	4.1—Natural Attenuation of Pu§	5.1—Long-Term Hydraulic Performance*
1.2—Residual Waste Sampling†	2.2—Chemical Transition Times‡	3.2—Groundwater Conditioning‡	4.2—Calcareous Zone Characterization†	5.2—Long-Term Erosion Protection Design*
1.3—Residual Waste Volume†		3.3—Shrinkage and Cracking†	4-3—Environmental Monitoring†	
1.4—Ancillary Equipment Inventory*		3.4—Grout Performance†		
1.5—Waste Removal (As It Impacts ALARA)*		3.5—Basemat Performance‡		
		3.6—Grout Stabilization (As It Impacts ALARA)*		
*Lower Priority				
†Medium Priority				
‡High Priority Dependent or More Difficult *(The monitoring factors in orange‡ are risk-significant to DOE's PA, but the need for their implementation may be dependent on results of other monitoring factors. Because the monitoring factors in orange‡ are also expected to be more difficult to study or support, work on monitoring factors in red§ are recommended first.)*				
§High Priority Recommended				

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