

Performance Assessment Progress for the F-Tank Farm at Savannah River Site - 10111

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ABSTRACT

The Savannah River Site (SRS) has completed a Performance Assessment (PA) for the F-Tank Farm (FTF) to support the closure documentation process [1]. The FTF is one of two liquid radioactive waste storage areas at the SRS and the location of the first two tanks closed in the Department of Energy (DOE) complex in the late 1990's. SRS plans to close the next two tanks in FTF prior to the Federal Facility Agreement (FFA) deadline of 2012. In order to commence tank grouting for final closure, several closure documents are necessary including a Section 3116 Waste Determination and South Carolina permit closure documents. The FTF PA was written with consideration of the various documents necessary for final closure and the information necessary to inform the document conclusions.

The FTF PA has been reviewed by applicable stakeholders (e.g., South Carolina Department of Health and Environmental Control, Nuclear Regulatory Commission, and Environmental Protection Agency) and comments have been addressed. Several areas of particular interest have become evident during PA development. The purpose of this paper is to discuss these topics and share lessons learned in these areas. An example of an area of interest is modeling "Conservatism" and how the complexity of the FTF models and the large number of systems and parameters included in the models have made determination of what can be considered "conservative" with regard to an individual system/parameter difficult. Other subjects to be covered include: Temporal/Spatial complexity in the FTF models, integration of independent sub-models into the FTF transport models, Benchmarking between multiple FTF models, probabilistic modeling insights, and the benefit of multiple FTF analyses (including barrier analyses).

INTRODUCTION

The Savannah River Site (SRS) is a U.S. Department of Energy (DOE) facility located in south-central South Carolina, approximately 161 kilometers (100 miles) from the Atlantic Coast. The major physical feature at SRS is the Savannah River, approximately 32 kilometers (20 miles) of which serves as the southwestern boundary of the site and the South Carolina-Georgia border. The SRS includes portions of Aiken, Barnwell, and Allendale Counties in South Carolina. The SRS occupies an almost circular area of approximately 803 square kilometers (310 square miles) and contains production, service, and research and development areas.

The F-Area is in the north-central portion of the SRS and occupies approximately 1.5 square kilometers (364 acres). The F-Area Tank Farm (FTF) is an active liquid waste storage facility operated by Savannah River Remediation, LLC (SRR), the Liquid Waste Operations contractor. The FTF is in the north-central portion of the SRS and occupies approximately 22 acres within

F-Area. The FTF consists of 22 carbon steel waste tanks and ancillary equipment such as transfer lines, evaporators and pump tanks. The FTF carbon steel waste tanks store (or once stored) liquid radioactive waste generated primarily from chemical separations processes. There are four tank designs in FTF (Types I, III, IIIA and IV) which have unique design features that impact the Performance Assessment (PA) results. Tank 17 and Tank 20 have already been filled with grout and closed via a South Carolina and Environmental Protection Agency (EPA) reviewed and approved Closure Plan and Closure Modules. Figure 1 presents the general layout of FTF including the storage tanks and principal ancillary equipment.

The FTF PA was prepared to support the eventual closure of the FTF underground radioactive waste tanks and ancillary equipment. The PA provides the technical basis and results to be used in subsequent documents to demonstrate compliance with the pertinent requirements identified for final closure of FTF including those in DOE Order 435.1 [2], the *Ronald W. Reagan National Defense Authorization Act (NDAA) for Fiscal Year 2005* Section 3116 [3], and South Carolina Department of Health and Environmental Control (SCDHEC) industrial wastewater regulations.

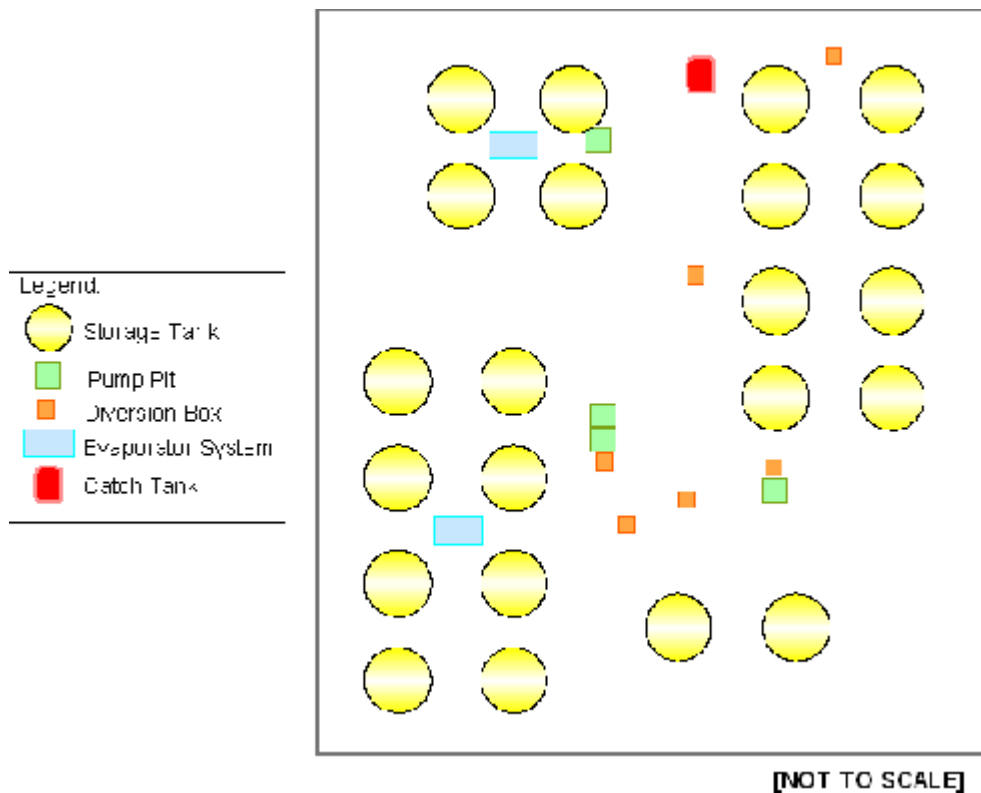


Fig. 1. General Layout of F-Tank Farm.

FTF PERFORMANCE ASSESSMENT

The FTF PA modeling consisted of a hybrid approach of both deterministic modeling for compliance results and probabilistic modeling for sensitivity and uncertainty analyses. The PA considered multiple points of assessment, including 100 meters from the FTF boundary and at the stream seep lines which intersect the aquifers under the area. The PA determined doses for a member of the public from all exposure pathways and inadvertent intruder as well as compared groundwater concentrations to Maximum Contaminant Levels.

Modeling Approach

To prepare for modeling of FTF, SRS conducted several new testing and computational activities. The physical and chemical properties were determined via analytical testing for the cementitious materials in the closed tank system including the reducing fill grout and concrete walls and basemat. Key properties included the hydraulic conductivity, porosity, and distribution coefficients for numerous radionuclides. Computational work included determining solubility values for various radionuclides, closure cap design and infiltration estimates, steel liner life estimates, updated bioaccumulation factors and consumption rates for SRS and residual inventory estimates.

As mentioned previously, the FTF PA employed a hybrid modeling approach. A deterministic evaluation was used to assess the base case and perform single parameter sensitivity analyses and utilized the PORFLOW computer code. The base case evaluation yielded a single result utilizing best estimate input parameters. A stochastic evaluation was used for the uncertainty analyses and sensitivity analyses and utilized the GoldSim platform with distributions for a large number of input parameters. The deterministic evaluation modeled flow and transport in both the near field and far field and the flow parameters were utilized in a more simplified analytical model for stochastic evaluation. The deterministic model results were benchmarked against the stochastic model to ensure consistency in model behavior. The stochastic evaluation modeled transport in both the near field and far field. The stochastic evaluation ensured that collective impacts were evaluated in the uncertainty analysis and sensitive parameters were identified in the sensitivity analysis. Figure 2 presents a graphical depiction of the modeling parameters for the deterministic and stochastic models.

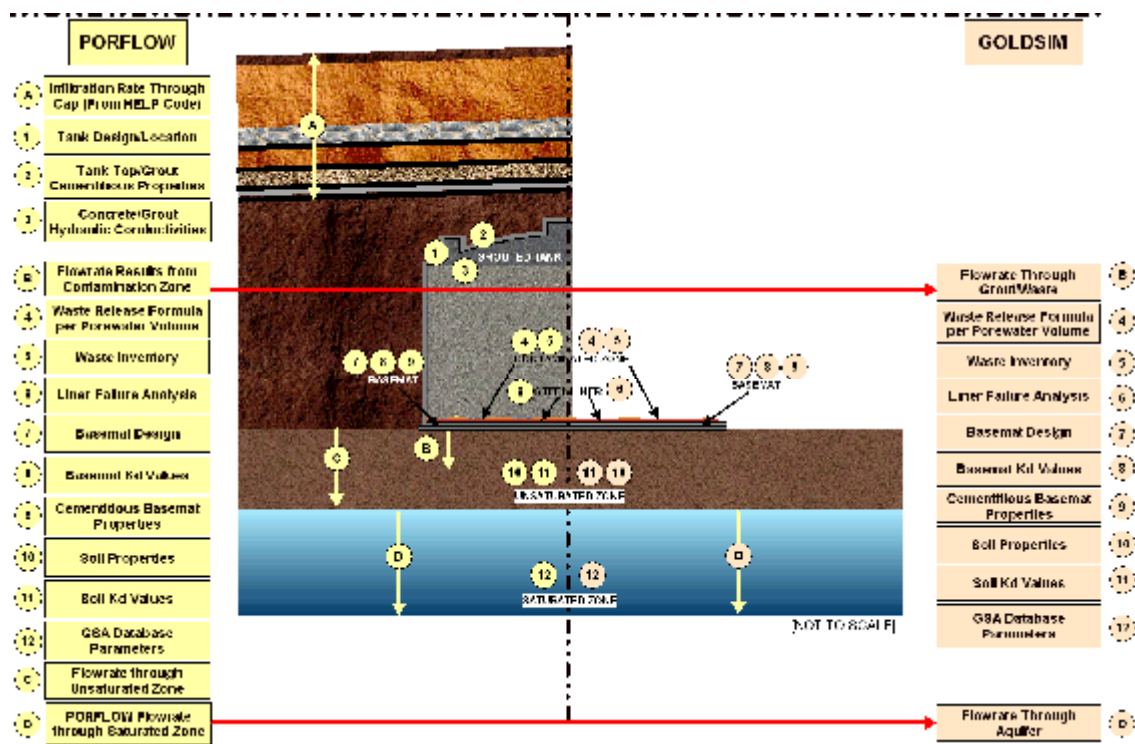


Fig. 2. Depiction of FTF Modeling Approach. Modeling Results

The FTF sits on a groundwater divide and therefore future releases will flow along various flow paths. Figure 3 presents the flow path centerlines from analytical tracer particles released from the centerline of each tank and illustrates the diverse flow directions which terminate at the streams. The PA calculates of the following: potential radiological doses to a hypothetical member of the public (MOP) at 100 meters and at the streams; potential radiological doses to a hypothetical inadvertent intruder; radiological dose to a human receptor via the air pathway, radon flux, and water concentrations. All of these calculations were performed to provide results over a minimum of 10,000 years. The water concentrations were calculated for both radioactive and non-radioactive contaminants at multiple locations outside FTF which will be used by future closure documents.

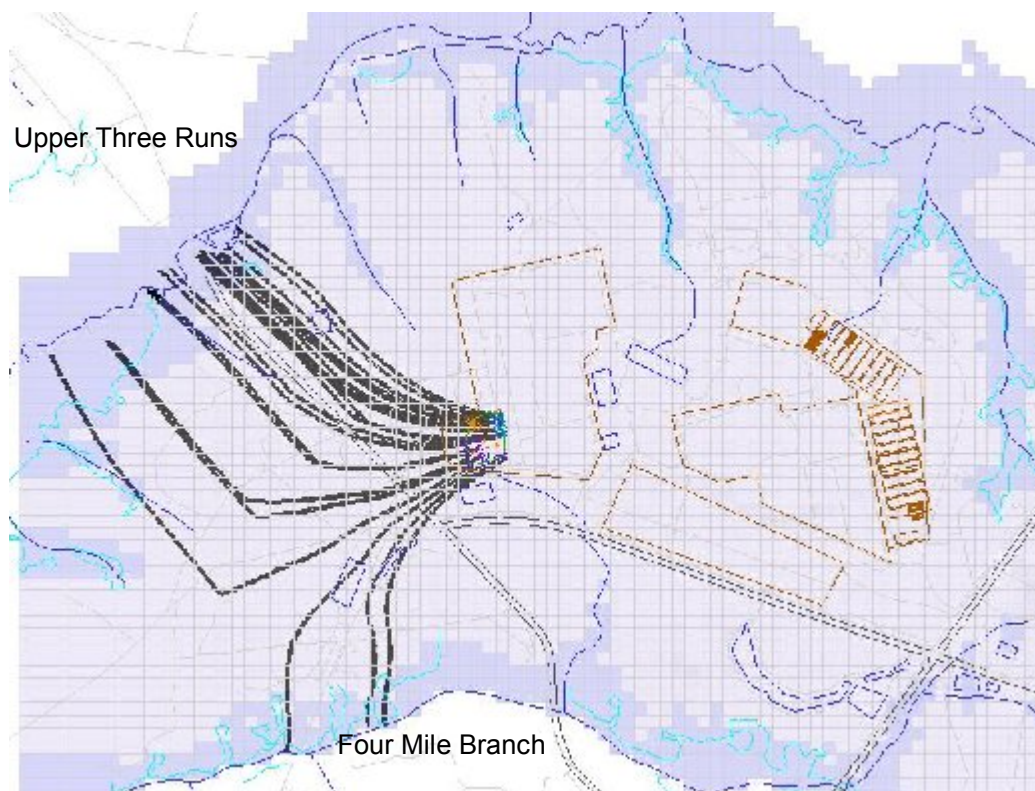


Fig. 3. FTF tank flow paths.

CURRENT STATUS AND INSIGHTS GAINED

The PA has been reviewed by applicable stakeholders (e.g., South Carolina Department of Health and Environmental Control, Nuclear Regulatory Commission, and Environmental Protection Agency). The overall review process was augmented by scoping meetings held during PA input data development that provided the FTF PA developers with up-front input understanding. The scoping meetings facilitated candid technical discussion on input parameters related to the tank farm-specific PA modeling. Comments on Revision 0 of the FTF PA have been received and addressed. Several areas of particular interest have become evident during PA development and while addressing stakeholder comments. The purpose of this paper is to discuss these topics and share insights gained in these areas.

Temporal/Spatial Complexity in the FTF models

The FTF model is inherently complex, with sudden releases of large quantities of radionuclides at different times. The FTF model has multiple parameters that have the potential to greatly influence radionuclide release (e.g., inventory, liner failure date, solubility transition time, key radionuclide solubility values, key radionuclide K_d values) such that system behavior can be erratic. There are multiple segments in the FTF model (e.g., tank grout, contamination zone, basemat) interacting and/or degrading at different times. The waste tanks and ancillary equipment are modeled individually, with the result being multiple waste sources are independently releasing inventory over time in differing flow directions. Since the inventory

can vary from waste source to waste source, different radionuclides can be of concern depending on the location. Some of the radionuclides of concern are also daughter products (e.g., Np-237 for Am-241), so the behavior of Np-237 can change even if no inputs directly affecting neptunium transport are changed. Because there is so much temporal/spatial complexity, it is difficult to make cursory judgements regarding changes to the model without considering all the parameters affected.

The influence of temporal/spatial complexity was confirmed by the multiple sensitivity analyses performed (in particular, the comprehensive barrier analysis discussed in more detail later). Changing a single model parameter such as tank concrete basemat thickness has a negligible impact on peak dose if the dose is dominated by a radionuclide such as Tc-99 (which has a fast travel time through the basemat), but can significantly change the peak dose if the tank involved contains radionuclides (e.g., Pu-239) that can be greatly retarded by the concrete. The effect of the single modeling input change is further complicated by the inventory available for release potentially varying over time depending on tank conditions and their influence on solubility. For example, the release of radionuclides from the tank contamination zone can be controlled by tank chemical conditions (e.g., pH), such that the timing of these changes effects the timing and inventory of releases.

Integration of Independent Sub-Models into the FTF Transport Models

The FTF integrated conceptual model consists of different segments, some of which were represented by independent sub-models. For example, the waste release model developed different solubility limits for different chemical states; the chemical state used in the model was determined in PORFLOW based on the PORFLOW calculated pore volumes. Since the sub-models were developed independently and may have different levels of conservatism, some shared input parameters may have different values from sub-model to sub-model. For example, the diffusion coefficient is different between the concrete degradation evaluation and waste tank liner failure evaluation. While the coefficient in the base case waste tank liner evaluation is a more expected value, the concrete degradation evaluation chose a very high coefficient to conservatively estimate degradation rates. Emphasis was placed on ensuring that individual sub-models are defensible, and the fact that two model segments may assume different values for the same parameter was not considered significant if the sub-models are valid and defensible. The challenge in this area is to balance the desire to link related input parameters with the necessity of managing the model size and complexity.

Benchmarking Between Multiple FTF Models

The intent of benchmarking was to assess the overall model results and adjust the model comprehensively so that the two models (deterministic and probabilistic) were aligned to the extent practical, not to attempt to calibrate individual tanks to match results. Comparison of the concentration results between the two models allowed system behaviors to be diagnosed, which was the intent of the comparison. Early benchmarking efforts identified some general inconsistencies between the model approaches which were corrected irrespective of the results comparison.

Additional benchmarking changes were made to refine the flow behavior extracted from the PORFLOW model into the FTF GoldSim model (e.g., changes to the plume function modifiers). A plume correction and benchmarking fraction are used within the portion of the FTF GoldSim model that simulates contaminant transport from the individual waste tanks to the evaluation locations (i.e., wells). The transport in the saturated zone is done using a 1-D line of Cells to cover the distance between the edge of the Tank and the line of wells 100-m from the FTF. This 1-D calculation is intended to work along a streamline, and the GoldSim Plume function is used to disperse the contamination laterally, so that each well will receive some input from each Tank. This plume correction, which is in the form of a fraction of the concentration found in the final Cell in the series (where the well is hypothesized to be), distributes the contaminant plume across the line of wells. A benchmarking fraction is also applied to the plume to better align the flow effects in the FTF GoldSim model with the GSA database flow data inherent in the FTF PORFLOW model.

Probabilistic Modeling Insights

The FTF Probabilistic (i.e., GoldSim) modeling runs included numerous modeling parameters and supporting input distributions (e.g., bioaccumulation factors, consumption rates, residual material inventory, tank basemat thickness, vadose zone thickness, tank configurations, distribution coefficients, solubility values, tank liner and ancillary equipment failure times). During model development, enhancements were made to the FTF probabilistic model in order to improve the Uncertainty/Sensitivity Analyses (UA/SA). This includes refinement of stochastic distributions, deletion of non-essential stochastics, and improved linkages between parameters where possible (e.g., saturated zone and vadose zone thickness). The decisions regarding where enhancements efforts would be concentrated were risk-informed, using numerous modeling runs to highlight which modeling parameters were having the most impact on results.

The stochastic analyses currently presented in the PA allow for the assessment of the uncertainties and sensitivities associated with the projected doses. Since the FTF GoldSim model does not independently model flow, the flow profiles used in the FTF GoldSim model are extracted from the FTF PORFLOW model. The six FTF modeling scenarios (i.e., cases) each have a unique flow profile. Most of the correlation in the FTF simulations center around flow, so the behavior tied to individual cases is correlated. Some parameters were allowed to behave independently because the future behavior is not so well understood as to make correlation obvious, and to impose a correlation would indicate knowledge not fully achieved. Many parameters are used to model material properties with many failure mechanism, some of which

share a common mode failure (e.g, concrete degradation accelerated due to a faulty grout formula used on multiple tanks) but many of which are used to non mechanistically represent independent events (e.g, concrete degradation accelerated due to a tank specific configuration issue, saturated thickness)

The FTF PA approach in general was to allow the parameters without obvious correlations to behave independently for each of the independent inventory sources. For parameters related to engineered barrier performance where direct correlation is not simulated, insights into the parameter impact can be drawn from deterministic sensitivity analyses (e.g., single parameter analyses, barrier analyses). An example where direct correlation is not simulated would include the relationship between steel liner failure and other parameters (e.g., closure cap degradation). Correlations with steel liner failure are difficult because the steel liner failure time distribution was calculated external to the FTF models, with the only correlation being a tie between the failure times and the FTF modeling cases

Benefits of Multiple FTF Analyses (Including Barrier Analyses)

As mentioned previously, the FTF PA utilizes a hybrid approach for modeling. The hybrid approach involves a Deterministic evaluation using PORFLOW computer code to determine base case results. Utilizing PORFLOW code provides Multi-Dimensional Modeling with complex systems interactions and numerous input parameters. The hybrid approach also includes a Stochastic evaluation performed with a probabilistic computer code (GoldSim). Utilizing the GoldSim code allows for multiple model runs and ensures collective impacts are considered (UA) and most sensitive parameters are identified (SA). The final intent of the UA/SA is to examine the combination of failures that leads to the highest dose consequences, and discuss the likelihood of these scenarios. Insight into the factors most affecting the magnitude and timing of the peak dose can be discovered by probing individual realizations, as well as by examining the peak of the mean dose over time.

The FTF PA will also include a comprehensive barrier analysis that clearly identifies barriers to waste migration and evaluates the capabilities of each barrier as understood from the results of the performance assessment. The barrier analyses will assess the contribution of individual barriers (e.g., Closure Cap, Grout, Contamination Zone, Tank Liner, and Tank Concrete) by comparing contaminant flux results under various barrier conditions. The barrier analyses will assess how flux results change with an individual barrier either intact or degraded, assuming the contribution of the other barriers has been minimized to the extent possible. Flux results assuming all barriers intact and assuming all barriers degraded will also be presented as a benchmark for the individual barrier evaluations.

It is important to consider the model results as complementary, recognizing each model has unique strengths and weaknesses. The insights from the revised UA/SA results, deterministic one-off analyses, and deterministic barrier analyses need to be related so as to clearly compare the probabilistic analysis results to the deterministic results, highlighting the factors influencing the peak dose as informed by the various analyses.

Modeling “Conservatism”

The complexity of the FTF models and the large number of systems and parameters included in the models have made determination of what can be considered “conservative” with regard to an individual system/parameter difficult. Dealing with the temporal/spatial complexity and progeny complexity discussed previously can lead to assumptions that intuitively appear to be “conservative” but may not be. Since transport times for different radionuclides can be significantly dissimilar (e.g., due to varying effects of barriers), model changes that slow transport for a single radionuclide can cause the peak dose to increase by allowing the affected radionuclide’s contribution to dose to overlap in a more pronounced way with a radionuclide unaffected by the model change. For example, delaying the release of a fast moving radionuclide (e.g., Tc-99) can cause the overall peak dose to increase by allowing the Tc-99 contribution to accrue with the contribution of a relatively slow moving radionuclide (e.g., Pu-239).

Model complexity resulting in outcomes that seem counterintuitive can be seen through the impact of tank liner failure time. A tank liner failing earlier will cause contaminants to escape the tank and travel down into the tank basemat earlier. With all other parameters unchanged, this would cause the contaminants released early to reach evaluation locations (e.g., a well at 100 meters) earlier. However, this early release may not produce an increase in the peak dose. For some waste tanks, the early dose peaks are dominated by Ra-226 related dose pathways, which are associated with Ra-226 parents (e.g., Th-230, U-234). Early liner failure allows the Ra-226 parents to exit the tank early. The longer the Ra-226 parents are contained with the tank liner, the more Ra-226 is produced prior to liner failure. The effect of the Ra-226 buildup is that when the liner does fail there is a “slug” of Ra-226 available for transport to the evaluation location and the associated peak dose is increased.

CONCLUSION

The FTF PA contains results for future comparison to performance measures for the regulatory time-frame of interest. The FTF PA provides documentation of the bases and methodology leading to the results and includes the necessary information for the development of future closure documents to support stakeholder closure decisions. The FTF PA has undergone review by the Department of Energy, SCDHEC, the EPA and the NRC. A revision to the FTF PA incorporating insights gained and addressing stakeholder comments is being prepared and is scheduled for issuance in 2010.

The primary insight gained would be that the impacts of the individual radionuclides should be assessed independently for the FTF and there is danger in generalizing the effect of parameters on dose. The effect of barriers can vary greatly depending on the individual radionuclide involved and trying to associate a single trait to a barrier can be difficult, if not impossible.

REFERENCES

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