

10. SIMULATIONS

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10.1 OVERVIEW

Although there is contamination currently in the groundwater underneath the Hanford Site (see [Chapter 2](#) for a summary and [Chapter 23](#) for a fuller discussion), more concern is expressed about suspected larger groundwater contamination levels in the future. However, future groundwater impacts cannot be extrapolated from past groundwater data. Instead, the total system (source, vadose zone, and groundwater) must be modeled using computer simulations to estimate future groundwater impacts from tank waste sources.

Computer simulations are used to estimate future impacts, particularly to groundwater. The goal is to understand how the total system (natural and man-made) behaves over time.

The goal of using simulations is to understand how the total system behaves. The underlying philosophy of performing simulations is given in the [next section](#). The following two sections describe simulation advances that have occurred in generating Field Investigation Reports (FIRs) ([Section 10.3](#)) and the Single-Shell Tank System Performance Assessment ([Section 10.4](#)). The chapter concludes with the relationship with other Hanford Site modeling efforts. More information on what we know from simulations is given in [Chapter 27](#).

10.2 PHILOSOPHY

The philosophy for performing computer simulations is to use the simplest model that adequately simulates the system. The complexity of the model is consistent with the level of knowledge of the system. The model uses processes and data that provide results ([Knepp 2002a](#)) for the best estimate of impacts (though, if necessary, with a bias toward larger impacts).

The dimensionality used in vadose zone modeling performs a useful example. The system is, in reality, three-dimensional. There are finite man-made structures. While having symmetry in one or two-dimensions, they are not uniform in all three-dimensions. The natural system varies as a function of depth and its layers are tilted relative to each other. The Tank Farm Vadose Zone Program has modeled the vadose zone underneath the SX Tank Farm in three dimensions, but has found that the results from two-dimensional vadose zone analyses are practically identical. However, the results of one-dimensional vadose zone simulations were far different. This is quite understandable, because important effects (for example, water shedding by the tank structures, tilting and bending of vadose layers) cannot be modeled in one dimension; whereas adding the third dimension does not add significant new effects. Thus, the Program performs most of its vadose zone modeling in two dimensions (so as to perform many more simulations) and occasionally validates the results of those runs using three-dimensional simulations.

10.3 SIMULATIONS OF PAST TANK SYSTEM RELEASES

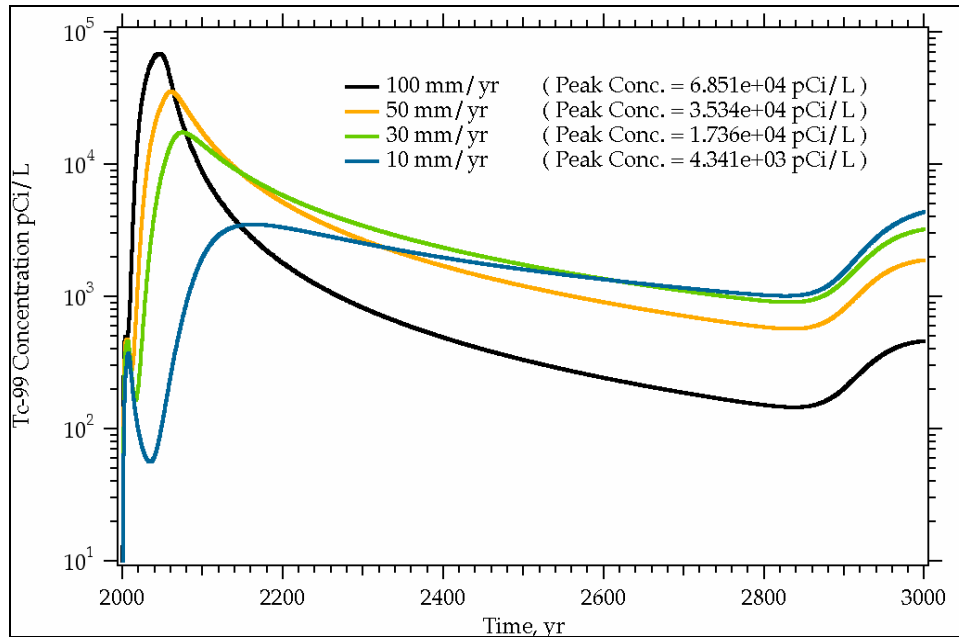
Chapter 4 of the Field Investigation Reports (FIR, [Knepp 2002a](#), [Knepp 2002b](#), [Myers 2005](#), [Connelly 2007a](#), and [Connelly 2007b](#)) describes simulations of the impacts from past releases from the tank farms. From the beginning in S-SX Tank Farms, the simulations not only estimate what we think will happen, but also provide simulations for different values of key systems parameters and for different remediation scenarios. Thus, the impact of different amounts of water entering the sediments is explicitly calculated in all of the Field Investigation Reports. The first FIR ([Knepp 2002a](#)) investigated the sensitivity of groundwater impact to shape (or extent) of the vadose zone plume that started the analysis. The FIRs investigate the effect of placing a temporary surface moisture barrier over the farms. The analyses in each of the FIRs were to understand important features of the system.

Another key approach of the FIR modeling is the use of an initial condition that reflects the year 2000, rather than that of 1940 (just before the tank farms were constructed). Thus, the initial condition of the simulation describes the plumes in the vadose zone in the year 2000 as determined through characterization and monitoring, rather than having the initial condition being intact tanks. This FIR initial condition is more defensible since there are insufficient data to characterize the actual leak events between 1940 and 2000. The volume and composition of the leaks are fairly well known (see [Chapter 9](#) and [Chapter 17](#)). However, the location and duration of the leaks into the vadose zone are poorly known, as is how the tank structure interacted with the released fluids. In addition, as discussed in the next paragraph, complex processes affect the initial history of the leaked fluids.

[Figure 10-1](#) displays the estimated peak technetium-99 concentration in groundwater at the edge of the S-SX Tank Farms at various times as a function of recharge (the amount of water entering the subsurface) as described in the S-SX Field Investigation Report ([Knepp 2002a](#)).

Additional investigations were performed to determine if the conceptual models included all of the important features. Because of the decay of the radionuclides in the tank waste, the temperatures of the waste, tanks, and surrounding sediments are above normal. In some analyses, temperatures above the normal boiling point of water (212°F) have been measured. Steve Yabusaki of the Pacific Northwest National Laboratory performed simulations that included and ignored the temperature-dependent effects ([Knepp 2002a](#)). The results showed that use of the simpler model used in the FIRs was adequate, but other approaches (such as modeling the leak from the time it began) would need more complex treatment. Another set of sensitivity analyses looked at preferential flow (for example, through clastic dikes, usually a near-vertical geologic feature found at the Hanford Site). However, the inclusion of such features did not change the estimated groundwater impacts from simulations without such preferential flows.

Figure 10.1. Averaged Breakthrough Curves for Technetium-99 at the WMA S-SX Boundary for Various Recharge Rates



10.4 SINGLE-SHELL TANK FARM SYSTEM

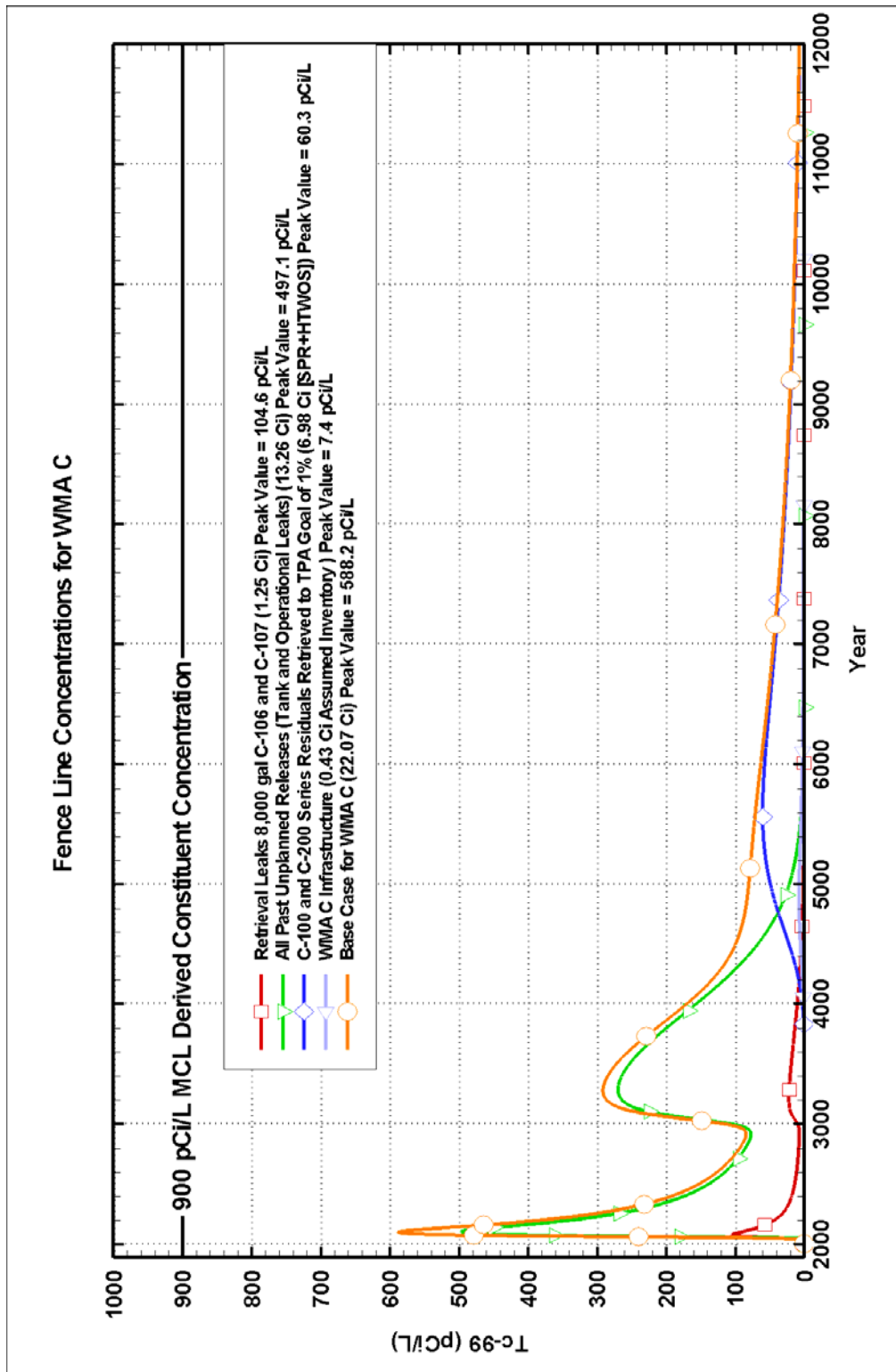
The simulations in the *Initial Single-Shell Tank Performance Assessment for the Hanford Site* ([DOE/ORP-2005-1](#)) go beyond those of the Field Investigation Reports. This performance assessment includes more sources and provides many more sensitivity analyses. Also, unlike the FIRs which only include a few farms, the performance assessment includes all of the single-shell tank farms.

The Single-Shell Tank Performance Assessment simulates not only past releases from tank farm facilities, but also the releases from residuals that may be left in the tanks and the auxiliary equipment (for example, pipelines and diversion boxes) and releases that could occur during tank waste retrieval. The inclusion of these new sources adds new processes and data needs.

The Single-Shell Tank Farm System Performance Assessment also performs many more sensitivity analyses than did the Field Investigation Reports. This is partly because of the larger scale of the analysis (that is, more tank farms, more sources in a tank farm) and because of the desire to better understand the system. Sensitivity analyses cover various recharge rates, past water pipeline leaks, residual waste models, vadose zone properties, and plume overlaps.

[Figure 10-2](#) displays the estimated peak technetium-99 concentration in groundwater at the edge of the C Tank Farm at various times for all sources.

Figure 10-2. Tc-99 Groundwater Concentrations from All WMA C Sources



10.5 INTERACTION WITH OTHER HANFORD ACTIVITIES

There are other modeling efforts being performed on the Hanford Site. Lessons learned from such modeling efforts can greatly aid the tank farm modeling efforts. During Phase 1 of the Tank Farm Vadose Zone Program, interactions were extensive with the performance assessments associated with the disposal of immobilized low-activity tank waste and with the composite analysis of Hanford Site's residual waste.

The immobilized low-activity tank waste performance assessments ([Mann et al. 1998](#) and [Mann et al. 2001](#)) and the Integrated Disposal Facility analyses ([Mann et al. 2003](#)) used very similar methods and data to the simulations performed by the Tank Farm Vadose Zone Program. The main differences are the source terms (the immobilized low-activity tank waste performance assessments and Integrated Disposal Facility analyses dealing with treated/processed tank waste) and the availability of much more site-specific data at the Integrated Disposal Facility site. However, as discussed in [Chapter 27](#) (Future Impacts), the results, conclusions, and insights from all of these analyses are quite similar.

By its nature, the Hanford Site Composite Analysis ([Kincaid et al. 1998](#)) evaluated a much broader scale than the tank farms. However, in maintaining this document, much information on data, methods, and results have been exchanged. Consistent approaches and data have resulted.

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