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Nuclear Solutions, LLC
A Fluor Daniel Partnership

F-Tank Farm Performance Assessment Overview

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Topics for Discussion

- **Modeling Overview**
- **Modeling Segments**
- **Modeling Results**
- **Uncertainty/Sensitivity Analyses**

Modeling Overview

Hybrid Approach

- **Hybrid Approach used for FTF PA**
- **Deterministic evaluation used to assess base case and perform single parameter sensitivity analyses**
- **Stochastic evaluation used for Uncertainty Analyses (UA) and Sensitivity Analyses (SA)**
- **Hybrid Approach allows for more comprehensive and flexible assessment**

FTF PA Groundwater Modeling: Modeling Overview

Deterministic Evaluation

- **Deterministic evaluation utilizes PORFLOW computer code**
- **Deterministic evaluation models flow and transport for both near field and far field**
- **Deterministic model benchmarked versus probabilistic model**

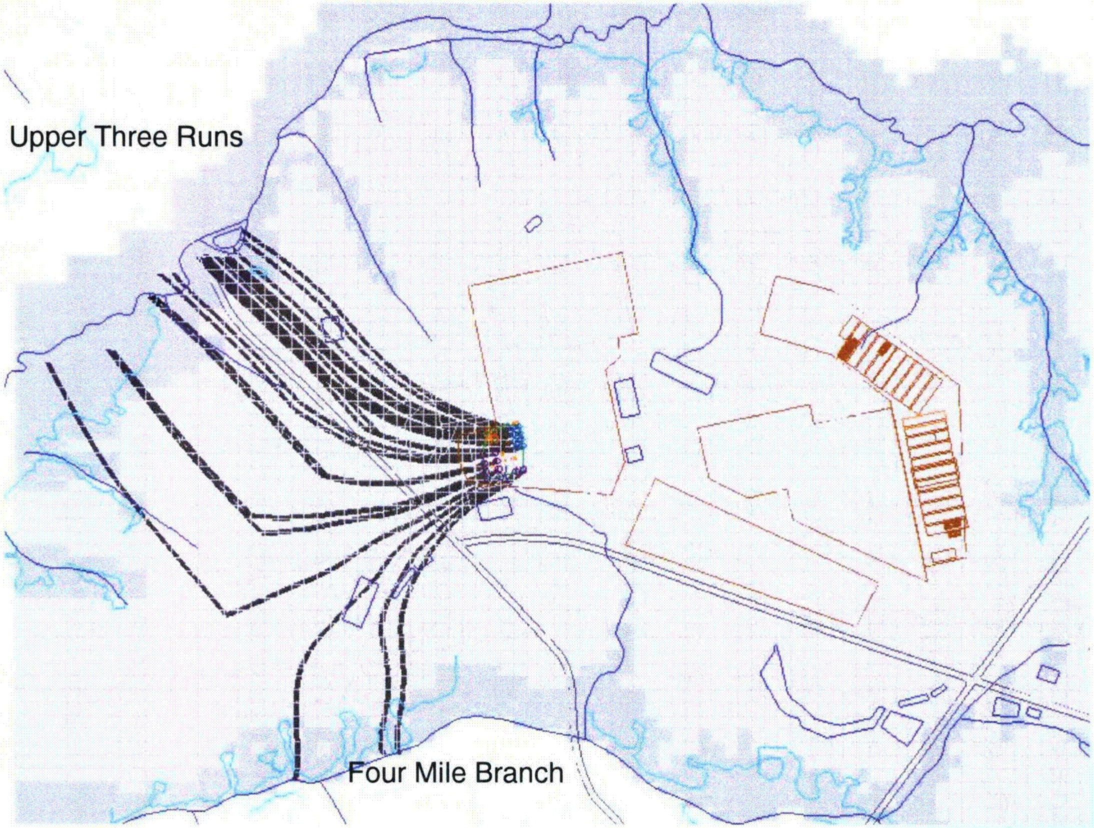
FTF PA Groundwater Modeling: Modeling Overview

Stochastic evaluation

- **Stochastic evaluation utilizes probabilistic code (GoldSim)**
- **Stochastic evaluation models transport for both near field and far field**
- **Stochastic evaluation ensures collective impacts are considered (UA) and indicates the sensitive parameters (SA)**

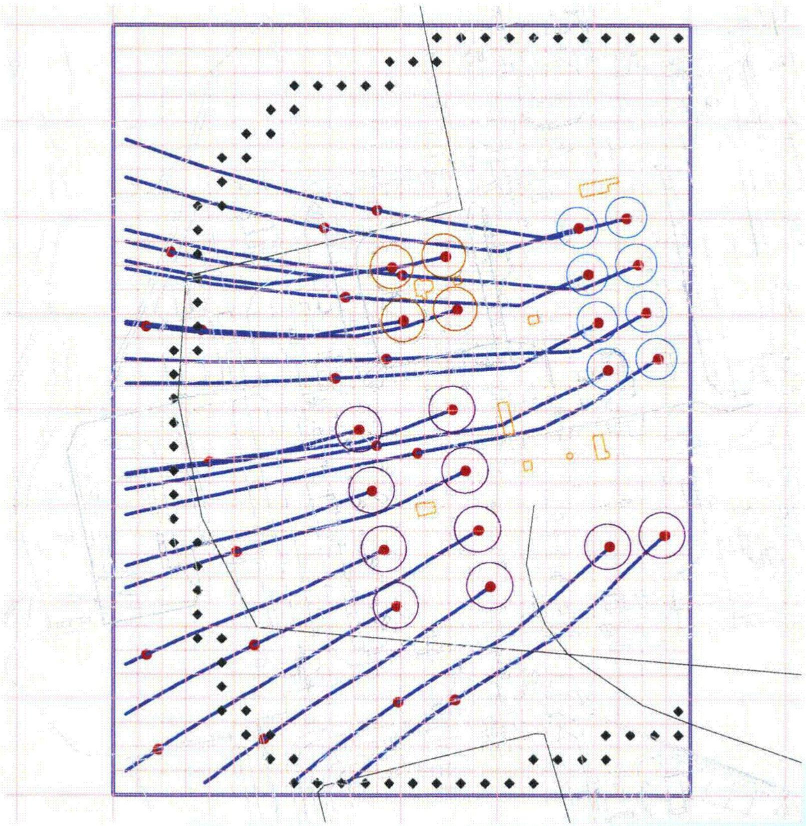
FTF PA Groundwater Modeling: Modeling Overview

PORFLOW GSA Flow Pathlines (Far Field) – PA Figure 4.4-12



FTF PA Groundwater Modeling: Modeling Overview

PORFLOW FTF Flow Pathlines (Near Field) – PA Figure 4.4-13



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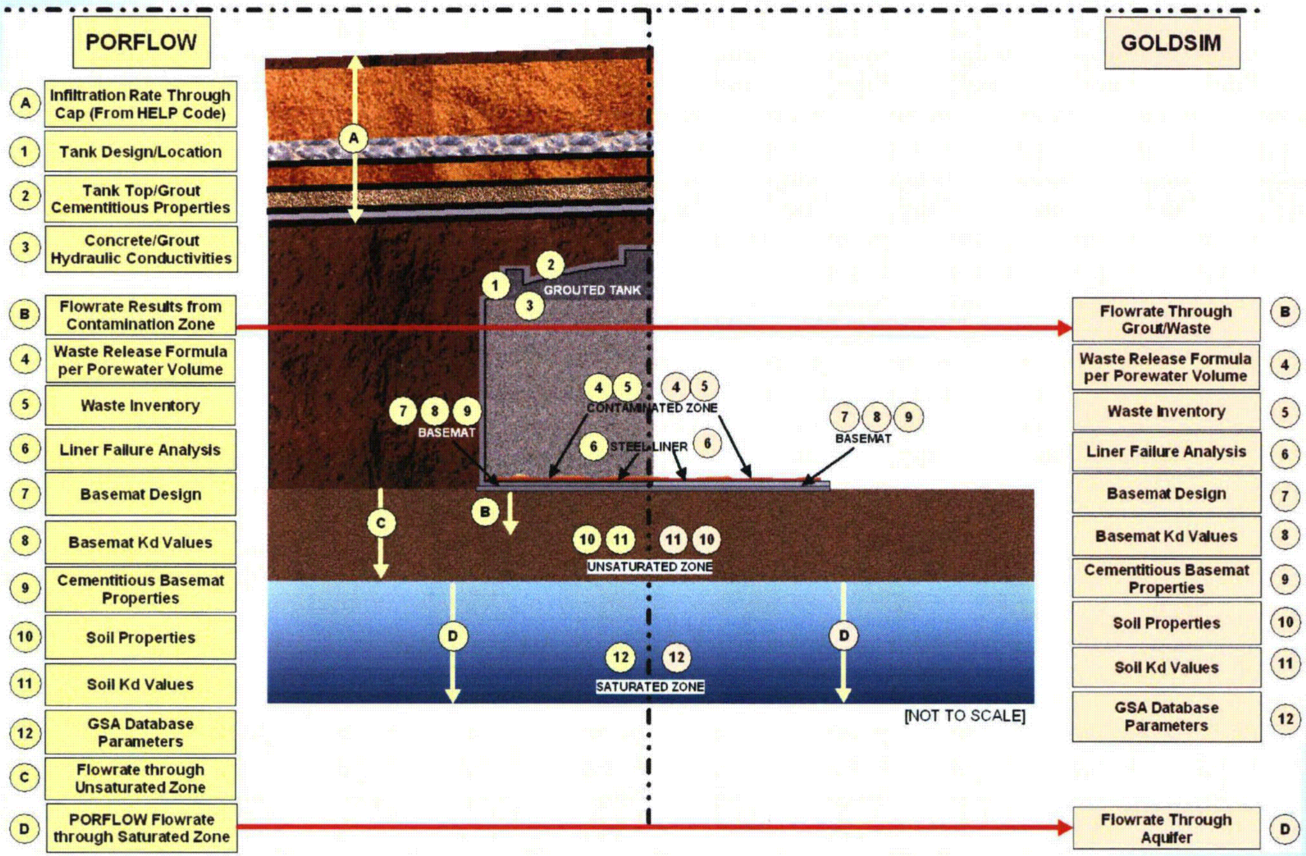
FTF PA Groundwater Modeling: Modeling Overview

Conceptual Model Interactions

- **Waste tanks and ancillary equipment modeled independently**
- **Model simulates multiple segments interacting and/or degrading at different times**
- **Model analysis complicated by temporal-spatial complexity of simulation**

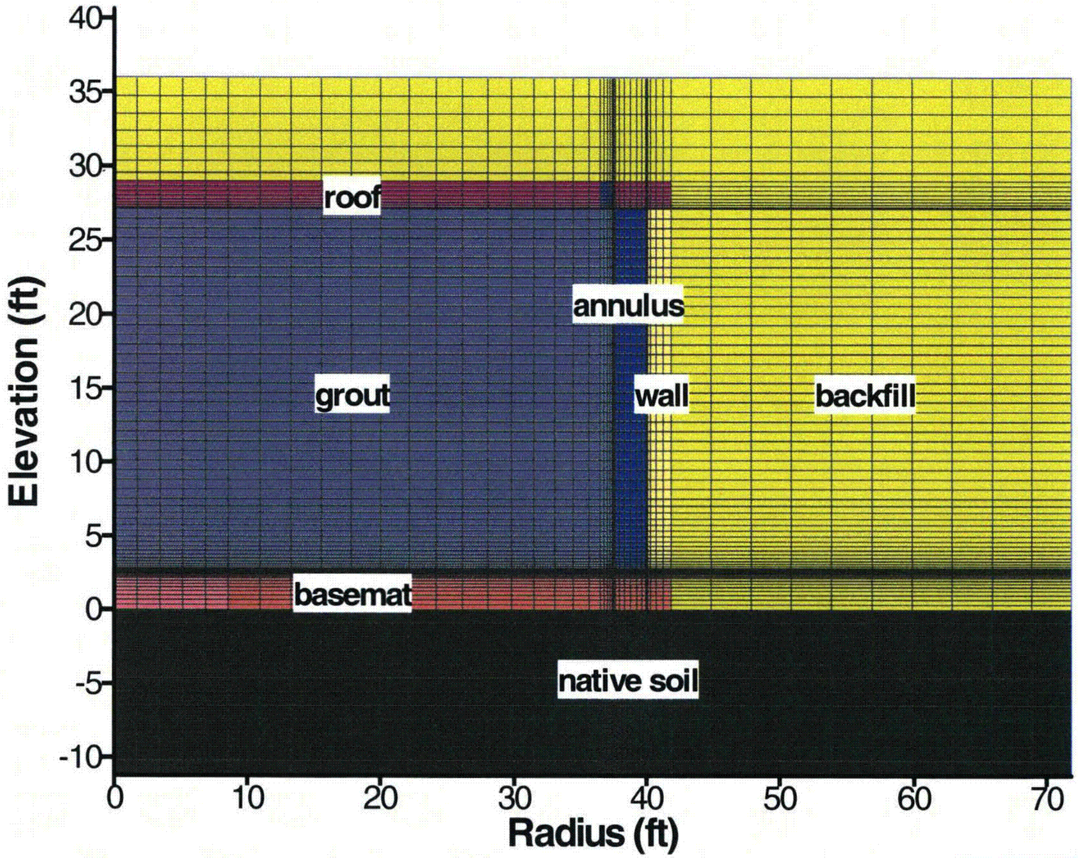
Modeling Segments

FTF PA Groundwater Modeling: Modeling Segments



FTF PA Groundwater Modeling: Modeling Segments

PORFLOW Type I Tank Model – PA Figure 4.4-14



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FTF PA Groundwater Modeling: Modeling Segments

Modeling Segments above Contamination Zone - PORFLOW only

- **Closure Cap – Independent model provides flow reaching tank top over time**
- **Waste Tank Concrete Top – Hydraulic degradation modeled over time in separate analysis, with results input into PORFLOW**
- **Waste Tank Liner Top – Independent analysis provides PORFLOW model with liner failure time for Type I/III/IIIA tanks (Type IV tanks have no top liner)**
- **Waste Tank Grout – Hydraulic degradation modeled over time in separate analysis, with results input into PORFLOW**

FTF PA Groundwater Modeling: Modeling Segments

Waste Tank Contamination Zone (CZ) – PORFLOW and GoldSim

- **Waste tank residual inventory modeled as thin layer (i.e., the CZ) at the bottom of the tank**
- **Release rate of contaminants from the CZ is solubility controlled and is tied to the chemical properties (e.g., Eh, pH) of the tank pore water**
- **Release rate from the CZ is independent of the grout or CZ K_d**
- **The assumed solubility limit for each radionuclide varies depending on waste tank pore water chemistry and the controlling phase of the radionuclide being released**

FTF PA Groundwater Modeling: Modeling Segments

Waste Tank Contamination Zone - PORFLOW and GoldSim

- **Additional emphasis and analysis was placed on those radionuclides shown during initial modeling to have the most impact on peak dose (Pu, Np, U, Tc)**
- **The effect of pore water volumes passing through the waste tank (i.e., changes in pH and reducing capability) is included**
- **Independent analysis estimated number of pore volumes linked to transition between various chemical phases**

FTF PA Groundwater Modeling: Modeling Segments

Waste Tank Liner Sides and Bottom - PORFLOW and GoldSim

- **After leaving the CZ, contaminants do not leave the tank until the tank liner fails**
- **Tank liner analyses calculate failure times (for each tank type) independent of the flow and transport model**
- **Primary and secondary liners are modeled as failing simultaneously and completely**
- **Additional liner failure analyses performed to assess the impact on the base case of:**
  - incorporating additional failure scenarios
  - assuming "patch model" failure vs. simultaneous failure
- **In the probabilistic model, the waste tank liner was modeled utilizing different configurations**

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Waste Tank Basemat - PORFLOW and GoldSim

- **After contaminants exit the waste tank liner, they enter the concrete tank basemat located directly below the liner**
- **Waste tank basemat material properties are modeled as changing over time**
- **Material properties of the concrete impact both the flow rate through the basemat and the K_d value**

FTF PA Groundwater Modeling: Modeling Segments

Vadose Zone Beneath Waste Tank - PORFLOW and GoldSim

- **After contaminants exit the basemat, they enter the vadose zone (e.g., soil) beneath the waste tank**
- **The vadose zone material properties impact both the flow rate through the soil and the associated K_d values, with both being important to the model**
- **The vadose zone depth below each waste tank varies depending on the tank involved**

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Closure Cap Insights

- **Changes in infiltration rate do not significantly affect the flow model in the early years because the tank liner is still intact**
- **Since the closure cap reaches the steady state flow values relatively quickly, the cap has a minimal effect on peak doses.**

FTF PA Groundwater Modeling: Modeling Segments

Tank Top Concrete and Tank Grout Insights

- **Timing of waste tank top concrete and tank grout degradation affects the flow rate into and through the tank**
- **Early material degradation allows the steady state flow values to be reached earlier, but does not have a significant impact on flow as compared to other segments**

FTF PA Groundwater Modeling: Modeling Segments

Contamination Zone Insights

- **Modeled solubility limits control the release rate of contaminants from the CZ**
- **Solubility limits are very sensitive to residual inventory assumptions and pore water chemistry**
- **The CZ modeling segment has a significant impact on the peak dose results (both timing and magnitude)**

FTF PA Groundwater Modeling: Modeling Segments

Tank Liner Insights

- **Early liner failure tends to spread the releases out over a longer time period and has only a minor affect on magnitude of the dose peaks within 20,000 years**
- **Early liner failure can significantly impact the timing of the early peaks associated with some radionuclides**
- **Since the release rate of the radionuclides most affecting dose are solubility limited, their contribution to the peak doses are not greatly impacted by early liner failure**

FTF PA Groundwater Modeling: Modeling Segments

Tank Basemat Insights

- **Bypassing the basemat removes both the flow restricting and K_d impacts of the basemat**
- **Allowing contaminants to bypass the basemat has a minimal affect on tanks with thin basemats (Type IV tanks), but has a more appreciable affect when the waste tanks involved have a very thick basemat (e.g., Type I/III/IIIA tanks)**
- **Impact of the basemat can be very radionuclide specific depending on the K_d value of the concrete**

FTF PA Groundwater Modeling: Modeling Segments

Vadose Zone Insights

- **Vadose zone beneath the waste tanks has a very similar radionuclide-specific effect to that of the basemat**
- **Vadose zone depth can have a considerable affect if the vadose layer is thick or if the radionuclide in question has a high K_d in soil**

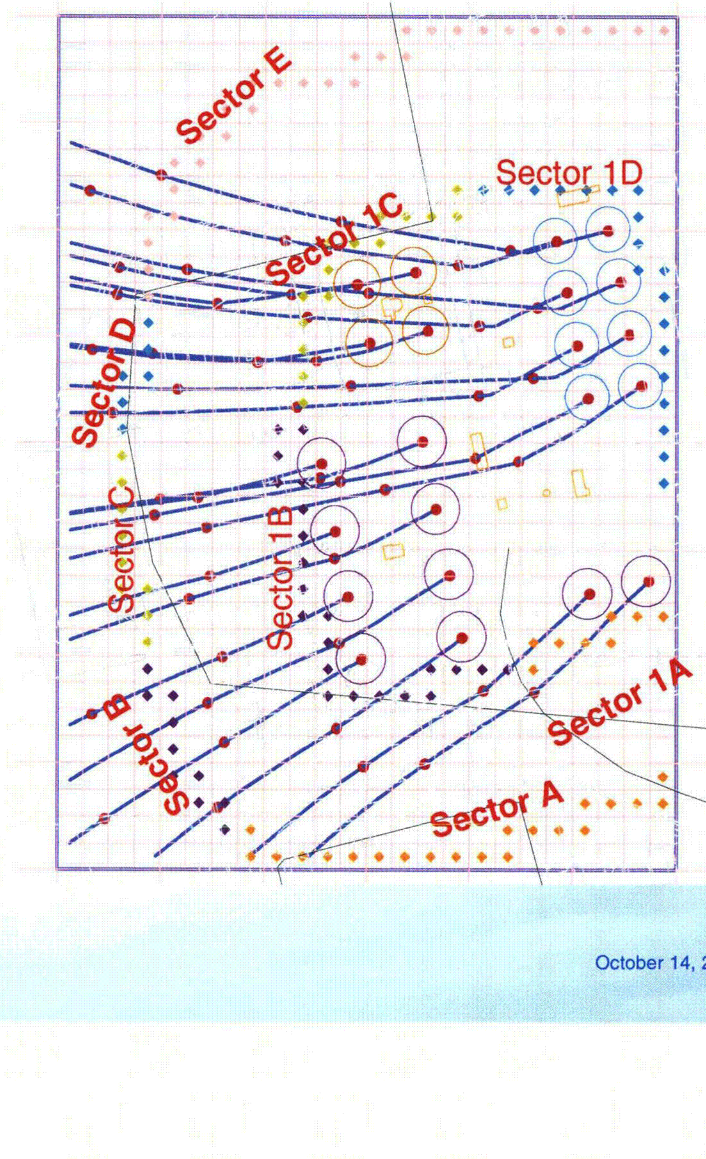
Modeling Results

FTF PA Groundwater Modeling: Modeling Results

FTF PA Sectors – Figure 5.2-5

Sectors used to allow the large amount of concentration data to be stored from PORFLOW and used by the GoldSim dose calculator model, and to allow variability in peak concentration for different areas of the FTF to be more easily evaluated.

Using the sectors to determine the highest groundwater concentrations causes the calculated peak doses to be higher than they actually are, since the peak concentrations are determined for each radionuclide independent of the location within the sector.



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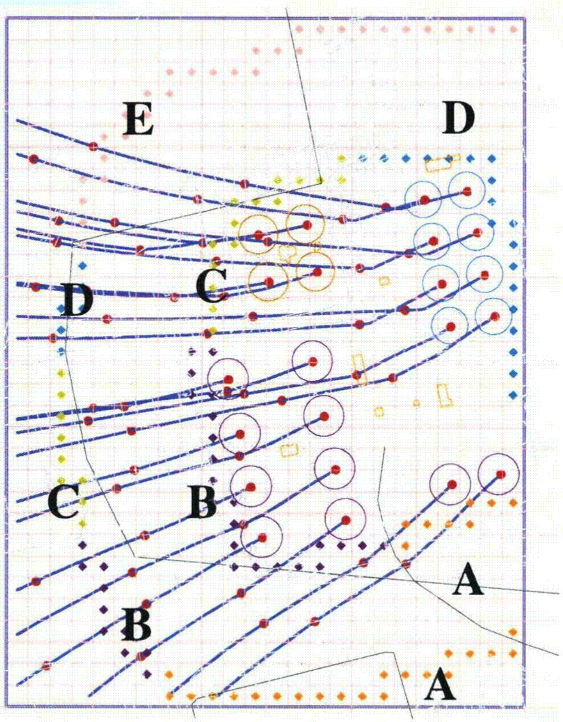
FTF PA Groundwater Modeling: Modeling Results

FTF PA Results – 100 Meters (Water) – PA Table 5.2-5



Sector	Highest Peak Dose in 10,000 Years	Highest Peak Dose in 20,000 Years
A	**0.20 mrem/yr (year 594)** Principal Pathways: Water Ingestion (46%) Fish Ingestion (26%) Vegetable Ingestion (21%) Principal Radionuclide: Tc-99 (72%)	**4.1 mrem/yr (year 17,390)** Principal Pathways: Water Ingestion (44%) Vegetable Ingestion (20%) Principal Radionuclide: Ra-226 (39%) Np-237 (60%)
B	**0.32 mrem/yr (year 598)** Principal Pathways: Water Ingestion (53%) Vegetable Ingestion (24%) Principal Radionuclide: Tc-99 (83%)	**3.9 mrem/yr (year 14,134)** Principal Pathways: Water Ingestion (61%) Vegetable Ingestion (27%) Principal Radionuclide: Ra-226 (98%)
C	**0.33 mrem/yr (year 596)** Principal Pathways: Water Ingestion (55%) Vegetable Ingestion (25%) Principal Radionuclide: Tc-99 (87%)	**2.2 mrem/yr (year 13,776)** Principal Pathways: Water Ingestion (61%) Vegetable Ingestion (28%) Principal Radionuclide: Ra-226 (89%)
D	**1.2 mrem/yr (year 10,000)** Principal Pathways: Water Ingestion (52%) Vegetable Ingestion (23%) Principal Radionuclides: U-233 (43%) Ra-226 (23%)	**5.9 mrem/yr (year 13,712)** Principal Pathways: Water Ingestion (53%) Vegetable Ingestion (25%) Principal Radionuclides: Ra-226 (51%) Th-229 (14%)
E	**1.3 mrem/yr (year 10,000)** Principal Pathways: Water Ingestion (53%) Vegetable Ingestion (24%) Principal Radionuclide: Ra-226 (36%) U-233 (27%)	**5.6 mrem/yr (year 13,722)** Principal Pathways: Water Ingestion (53%) Vegetable Ingestion (25%) Principal Radionuclides: Ra-226 (45%) U-233 (14%)

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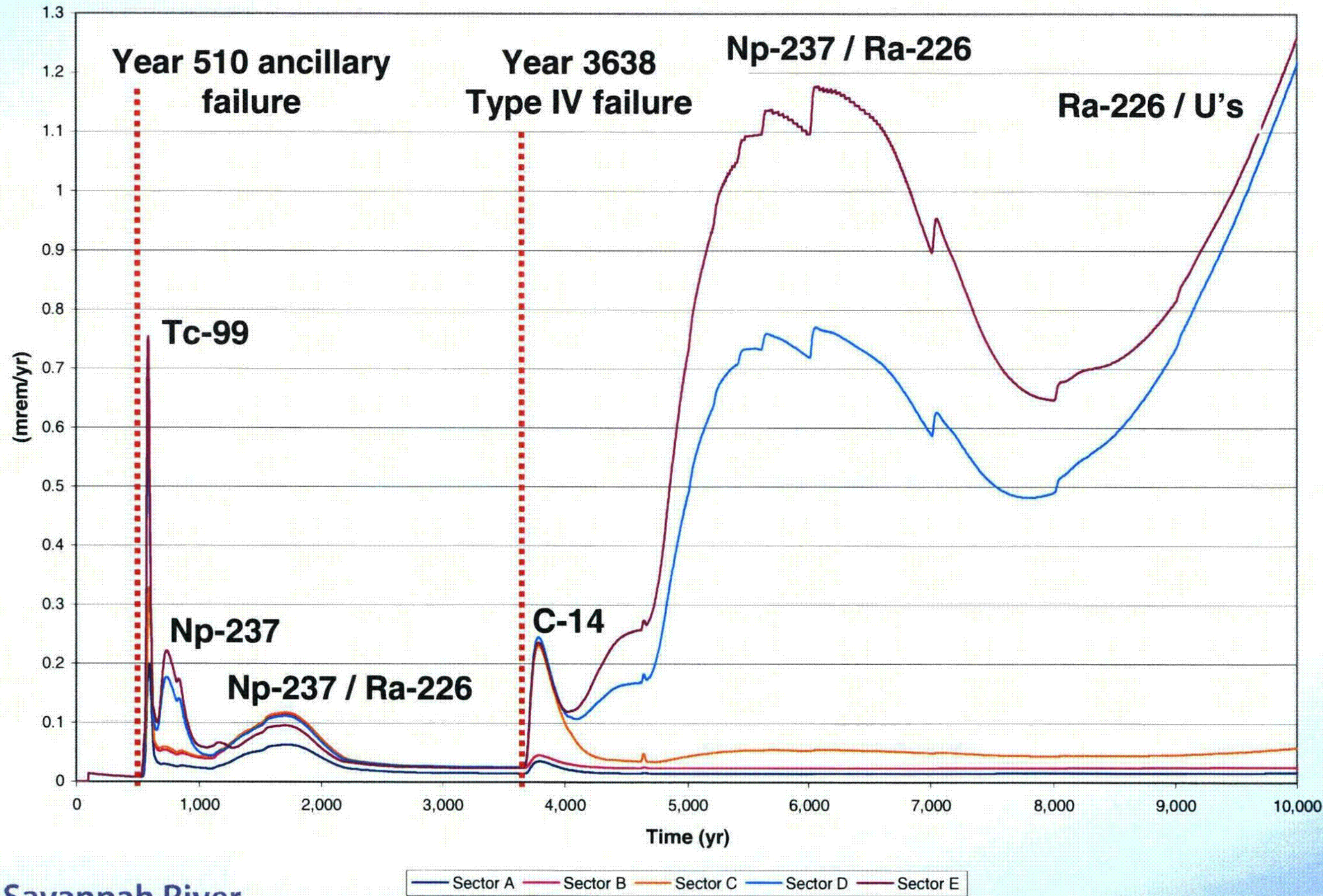
FTF PA Groundwater Modeling: Modeling Results

100m Sectors - 10,000 year results – PA Figure 5.5-1



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FTF PA Groundwater Modeling: Modeling Results

Ancillary Equipment Results – 100m Sectors

- **Peaks prior to year 3,600 are associated with ancillary equipment releases**
  - Peaks near year 580 are associated with Tc-99
  - Peaks near year 725 are associated with Np-237
  - Peaks near year 1,800 are associated with Ra-226 and also the tail end of the Np-237 release

FTF PA Groundwater Modeling: Modeling Results

Waste Tank Results – 100m Sectors

- **Peaks between years 3,600 and 12,700 are tied primarily to releases from the Type IV tanks**
- **Peaks near year 3,600 are associated with C-14 from the Type IV tanks**
- **Sector D and E doses between approximately year 4,000 and 10,000 have a significant Ra-226 contribution**
- **Ra-226 contribution is tied to the release and travel of U-238: since Ra-226 transport is faster than U-238 transport, the Ra-226 reaches the evaluation point before its parent**

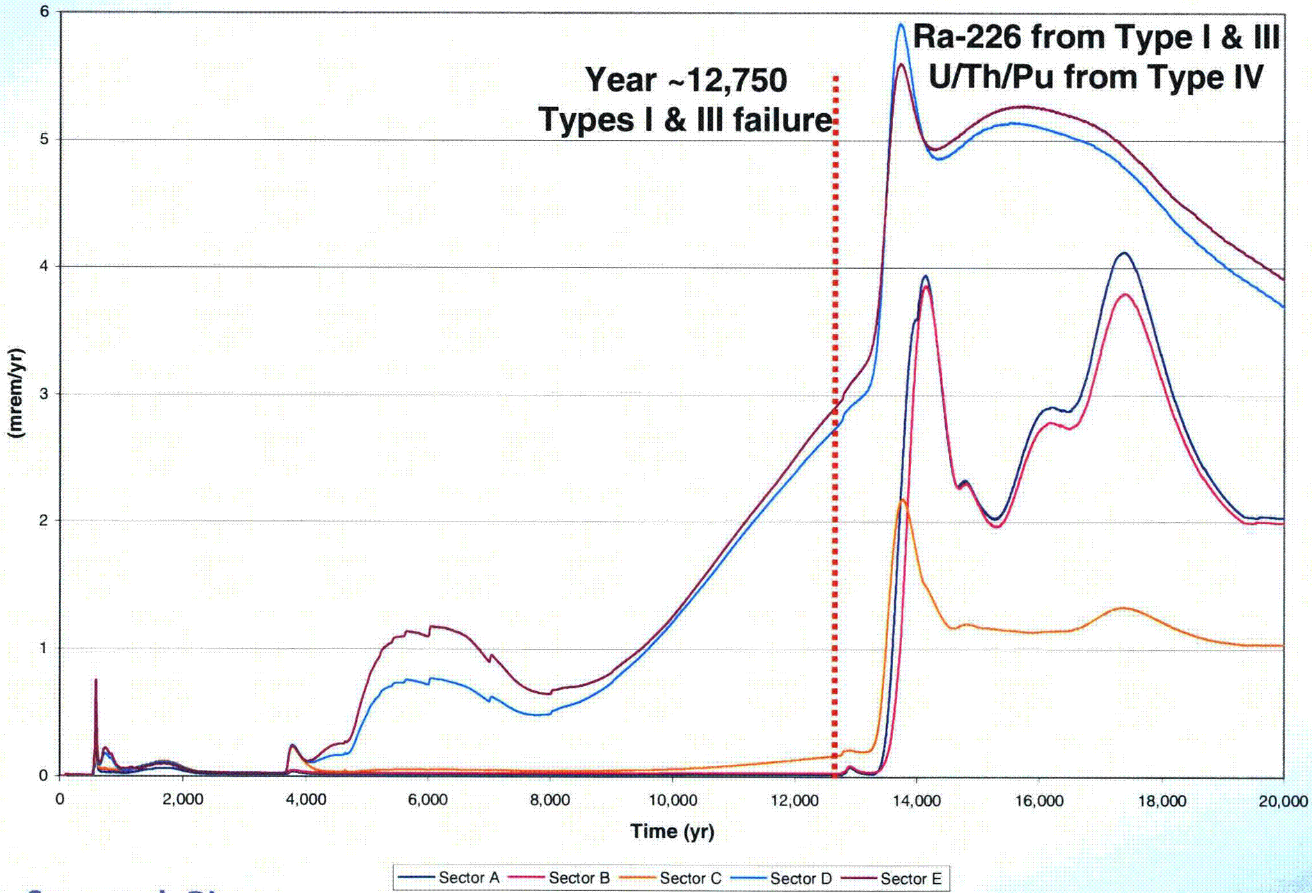
FTF PA Groundwater Modeling: Modeling Results

Waste Tank Results – 100m Sectors

- **Sector D and E peaks near year 6,000 are associated with Np-237 and Ra-226 from the Type IV tanks**
- **Sector D and E peaks near year 10,000 are primarily associated with Ra-226, but also with relatively slow moving radionuclides that are just reaching the evaluation point at year 10,000**

FTF PA Groundwater Modeling: Modeling Results

100m Sectors - 20,000 year results – PA Figure 5.5-2



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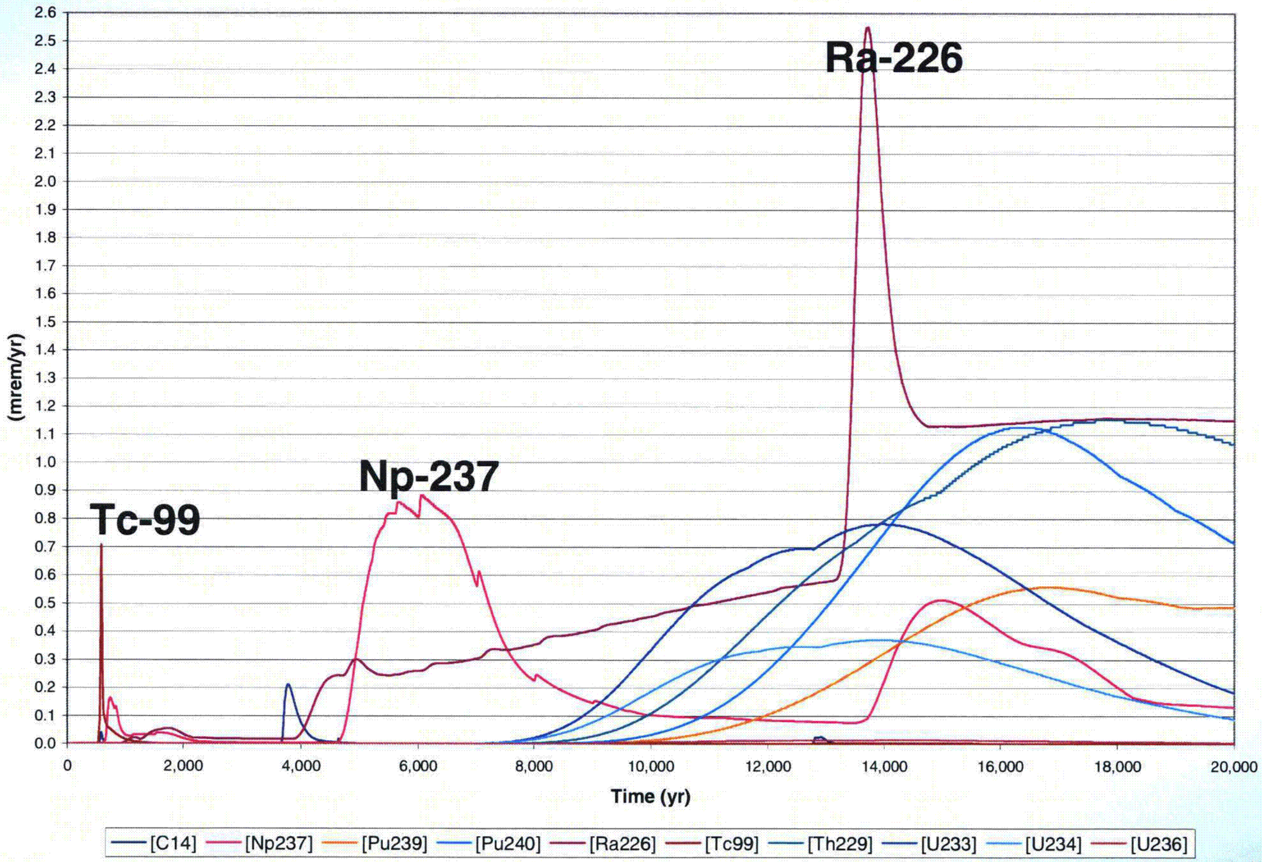
FTF PA Groundwater Modeling: Modeling Results

Waste Tank Results – 100m Sectors

- **Dose spike near year 14,000 is associated with Ra-226 and is tied to the liner failure dates (~ year 12,700) for the Type I and Type III/IIIA tanks**
- **Sector A and B peaks at year 16,000 and 17,500 are associated with Np-237 from the Type III tanks**
- **Np-237 (and its parent Am-241) are released from the Type III tanks after tank liner failure**
- **Sector C mirrors the dose profiles from the other sectors in many ways but always with a smaller magnitude dose**

FTF PA Groundwater Modeling: Modeling Results

100m Sectors – Peak Radionuclide Results – PA Figure 5.5-4



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FTF PA Groundwater Modeling: Modeling Results

100m Sectors (Water) – Peak Radionuclide Results – PA Table 5.5-2

Radionuclide	Contribution to Sector E Peak dose at year 10,000 (mrem/yr)	Percentage of Total Peak Dose (%)
C-14	<0.01	0
Np-237	0.10	8
Pa-231	0.02	2
Pb-210	<0.01	0
Pu-239	0.01	1
Pu-240	0.03	3
Pu-242	<0.01	0
Ra-226	0.45	37
Tc-99	<0.01	0
Th-229	0.11	8
Th-230	<0.01	0
U-233	0.33	26
U-234	0.19	15
U-236	0.01	0
U-238	<0.01	0
Total	**1.26**	**100**

FTF PA Groundwater Modeling: Modeling Results

100m Sectors –10,000 year dose by inventory source – PA Table 5.5-3

Waste Source	Contribution to Sector E Peak Dose at year 10,000 (mrem/yr)	Percentage of Total Peak Dose (%)
Tank 17	0.10	8
Tank 18	1.05	83
Tank 19	0.06	5
Tank 20	0.01	1
Transfer Lines	0.03	2
Other Sources	<0.01	<1
TOTAL	**1.26**	**~100**

FTF PA Groundwater Modeling: Modeling Results

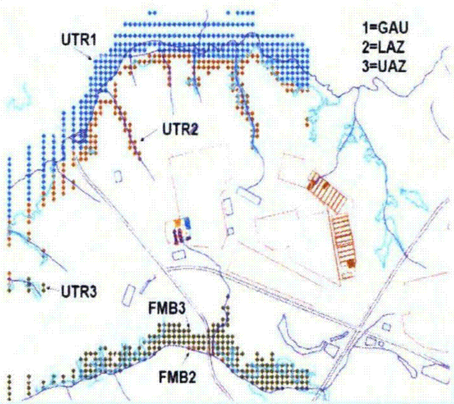
100m Sectors –10,000 year dose by pathway – PA Table 5.5-4

Pathway	Associated Contribution at year 10,000 (mrem/yr)	Percentage of Total Peak Dose (%)	Principal Radionuclide Pathway Dose (%)
Water Ingestion	0.67	52.8	Ra-226 (43%)
Vegetable Ingestion	0.30	23.7	Ra-226 (43%)
Shower Inhalation	0.21	16.6	U-233 (29%)
Garden Inhalation	0.069	5.4	U-233 (29%)
Finfish Ingestion	0.010	0.8	Ra-226 (91%)
Milk Ingestion	0.007	0.6	Ra-226 (76%)
Beef Ingestion	0.002	<1	Ra-226 (66%)
TOTAL	**1.26**	**100**	

FTF PA Groundwater Modeling: Modeling Results

FTF PA Results – Stream (Water) – PA Table 5.5-6

Sector	Highest Peak Dose in 10,000 Years	Highest Peak Dose in 20,000 Years
Fourmile Branch	**0.07 mrem/year (year 586)** Principal Pathway: Finfish Ingestion (86%) Principal Radionuclide: C-14 (85%)	**0.73 mrem/year (year 14,468)** Principal Pathway: Finfish Ingestion (46%) Principal Radionuclide: Ra-226 (97%)
Upper Three Runs	**0.21 mrem/year (year 3,788)** Principal Pathway: Finfish Ingestion (98%) Principal Radionuclide: C-14 (98%)	**0.21 mrem/year (year 3,788)** Principal Pathway: Finfish Ingestion (98%) Principal Radionuclide: C-14 (98%)



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FTF PA Groundwater Modeling: Modeling Results

Acute Intruder Results – PA Table 6.4-1

Acute Intruder Pathway Contributors	Peak Contribution (mrem)	Principal Radionuclide Pathway Dose (%)
Drill Cuttings Direct Exposure	1.53	Cs-137/Ba-137m (94%)
Drill Cuttings Ingestion	0.02	Am-241 (50%)
Drill Cuttings Inhalation	0.05	Am-241 (70%)
Total	**1.60**	

FTF PA Groundwater Modeling: Modeling Results

Chronic Intruder Results - PA Table 6.4-2

Chronic Intruder Pathway Contributors	Contribution to Peak (mrem/yr)	Principal Radionuclide Pathway Dose (%)
Vegetable Ingestion	71.6	Sr-90 / Y-90 (56%) Cs-137 / Ba-137m (44%)
Soil Ingestion	0.7	Am-241 (43%) Sr-90 / Y-90 (35%)
Other Pathways	0.5	- - -
Total	**72.8**	

FTF PA Groundwater Modeling: Modeling Results

Dose Results Insights

- **Type IV Tank releases dominate peak dose results in 10k year window**
- **Type I Tank releases contribute to Sector D and E peak dose results in 10k – 20k year window**
- **Type III Tank releases dominate Sector A and B peak dose results in 10k – 20k year window**
- **Type IIIA Tank releases have negligible impact on peak dose results**
- **Ancillary equipment contribution to dose appears early in 10k year window**
- **Late liner failure allows more daughter product ingrowth in the waste tanks, leading to higher peaks for initial releases**

Uncertainty/Sensitivity Analyses

FTF PA Groundwater Modeling: Uncertainty/Sensitivity Analyses

Multiple Analyses Performed

- **Probabilistic uncertainty analyses using the FTF GoldSim model**
- **Single parameter deterministic sensitivity analyses using the FTF PORFLOW model**
- **Selected parameter deterministic sensitivity analyses using the FTF GoldSim model**
- **Probabilistic sensitivity analyses using the FTF GoldSim model**

FTF PA Groundwater Modeling: Uncertainty/Sensitivity Analyses

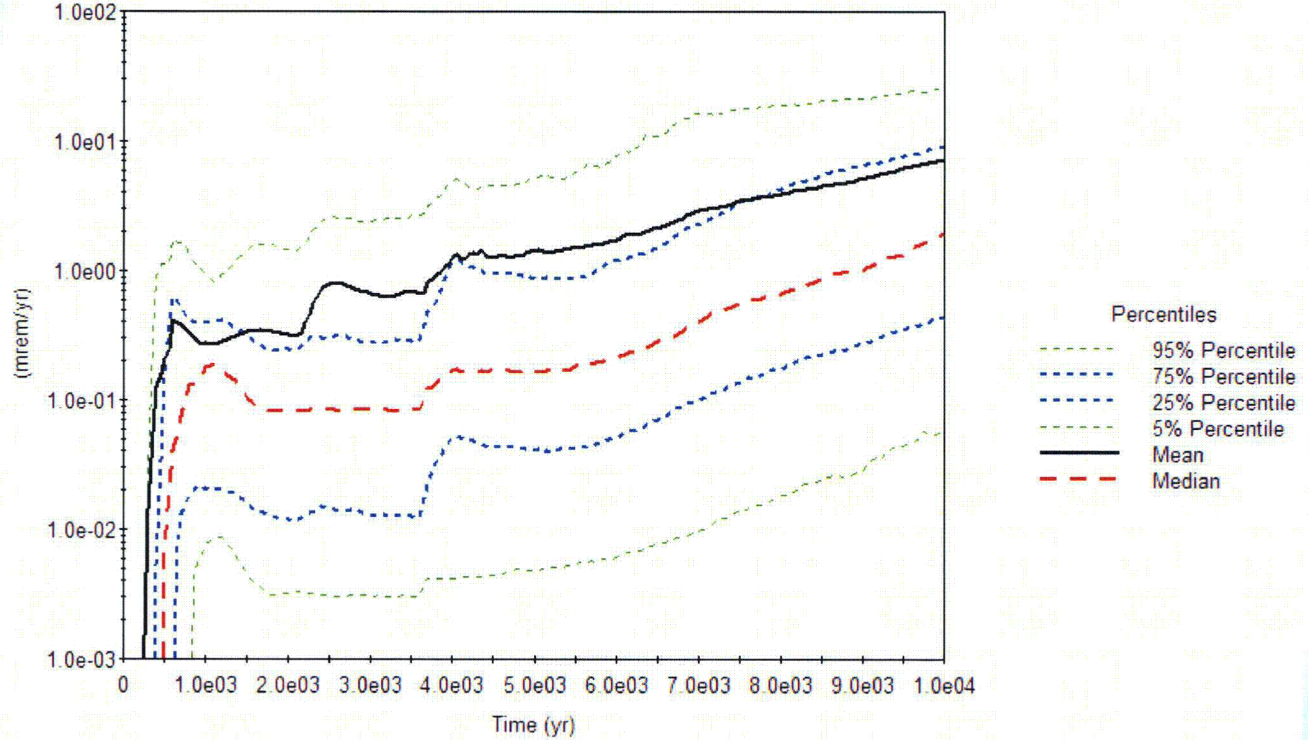
Probabilistic Uncertainty Analysis - GoldSim

Probabilistic model included numerous distributions:

- tank configurations
- consumption rates
- residual material inventory
- tank basemat thickness
- vadose zone thickness
- distribution coefficients
- pore volume transitions
- basemat fast flow
- solubility values (for Pu, U, Tc & Np)
- well depth
- tank liner and ancillary equipment failure times

FTF PA Groundwater Modeling: Uncertainty/Sensitivity Analyses

Statistical Results to 10,000 Years – PA Figure 5.6-20



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Single Parameter Deterministic Sensitivity Analysis

- **Single parameter sensitivity analyses were performed using the FTF PORFLOW model**
- **Two single parameter sensitivity analyses were performed using the base case configuration**
  - Waste tank inventory
  - Basemat and soil K_d values

FTF PA Groundwater Modeling: Uncertainty/Sensitivity Analyses

Single Parameter Deterministic Sensitivity Analysis

- **Waste Tank Inventory**
  - Fluxes calculated for two Type I Tanks (low case 0.5X, high case 1.5X) and for two Type IV Tanks (low case 0.8X, high case 1.2X)
  - Results show that for most radionuclides, the flux essentially varies linearly with the inventory, with exceptions (e.g., Pu-239, Pu-240, Tc-99, and U-238) being those radionuclides that are solubility controlled.
- **Waste Tank K_d**
  - Fluxes for Tc-99 and Pu-239 were calculated for a range of tanks adjusting the basemat and soil K_d
  - Results show that Tc-99 flux is relatively unaffected by K_d changes, while Pu-239 flux can be impacted when the material layer is thick

FTF PA Groundwater Modeling: Uncertainty/Sensitivity Analyses

Deterministic Sensitivity Analysis using FTF GoldSim probabilistic model

- **Additional sensitivity analyses performed using the GoldSim probabilistic model in deterministic mode.**
- **The GoldSim single parameter sensitivity analyses were used to compare the baseline dose results to configurations which changed individual parameters to reflect other degradation conditions:**
  - GoldSim base case deterministic run
  - Base case parameters with 25% of flow bypassing the basemat
  - Base case parameters with early liner failure
  - Base case parameters with early liner failure and with instantaneous transition to oxidized Region III parameters

FTF PA Groundwater Modeling: Conclusions

FTF PA Conclusions

- **FTF Performance Objectives will be met with reasonable assurance**
- **Uncertainty analysis shows that Performance Objective compliance is not significantly impacted by parameter variability**
- **Use of multiple sensitivity analyses allows for an increased emphasis on parameters of significance**

Notes

Notes

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