TOC-WP-14-4902 -FP
Revision 0

Preliminary Performance Assessment for the Waste Management Area C at the Hanford Site in Southeast Washington - 15331

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-08RV14800

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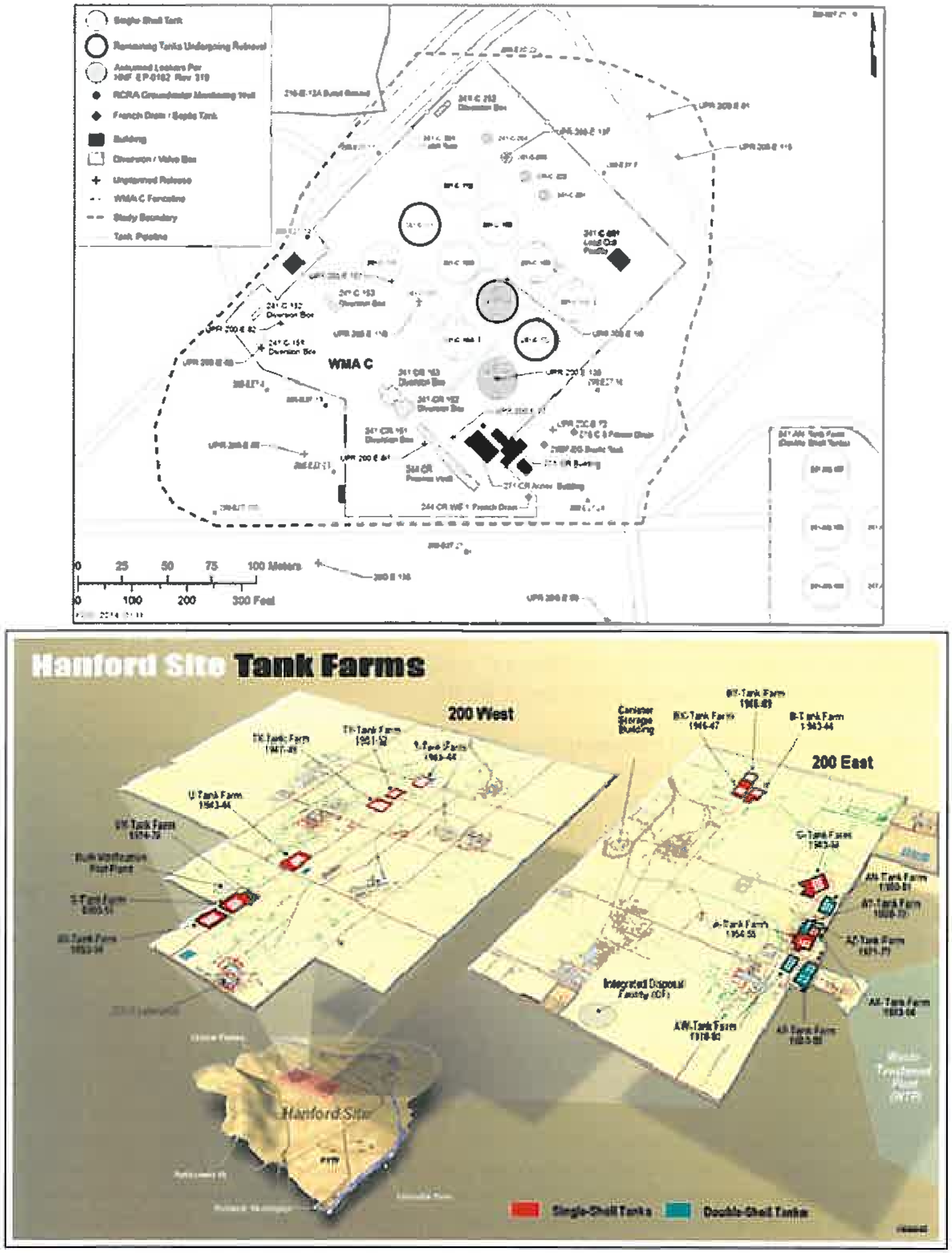
ABSTRACT

A performance assessment (PA) of Single-Shell Tank (SST) Waste Management Area C (WMA C) located at the U.S. Department of Energy's (DOE) Hanford Site in southeastern Washington is being conducted to satisfy the requirements of the Hanford Federal Facility Agreement and Consent Order (HFFACO), as well as other Federal requirements and State-approved closure plans and permits. The WMA C PA assesses the fate, transport, and impacts of radionuclides and hazardous chemicals within residual wastes left in tanks and ancillary equipment and facilities in their assumed closed configuration and the subsequent risks to humans into the far future. The part of the PA focused on radiological impacts is being developed to meet the requirements for a closure authorization under DOE Order 435.1 that includes a waste incidental to reprocessing determination for residual wastes remaining in tanks, ancillary equipment, and facilities. An additional part of the PA will evaluate human health and environmental impacts from hazardous chemical inventories in residual wastes remaining in WMA C tanks, ancillary equipment, and facilities needed to meet the requirements for permitted closure under RCRA.

Preliminary results of the PA are evaluating the groundwater and air pathways to determine radiation exposure once radionuclides are released to the environment due to degradation of the engineered barriers. Results of the preliminary analyses conducted so far show that the proposed closure of WMA C tanks and ancillary equipment is expected to be well below the performance objectives during the 1,000-yr post-closure period of compliance. Inadvertent intruder analysis show doses from a well driller scenario would be below the 500 mrem performance measure for acute exposure but doses from a suburban gardener scenario would exceed the 100 mrem/yr performance measures for some tanks during the first 100 to 150 years after the 100-year institutional control period after closure.

INTRODUCTION

Waste Management Area C is one of seven WMAs (A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U) containing 149 SSTs built from 1943 to 1964. In general, the WMA C boundary is represented by the fence line surrounding C-Farm (Fig. 1). Waste Management Area C contains 12 100-series SSTs and 4 200-series SSTs that were constructed in 1943 to 1944 along with associated ancillary equipment (i.e., diversion boxes, pipes). It was placed in service in 1946, and used to store and transfer waste until mid-1980. Additional ancillary equipment (CR-Vault and CR diversion boxes) were added in the early 1950s. A comprehensive PA meeting the requirements of DOE Order 435.1 [1] and RCRA [2] closure analysis for WMA C is in the process of being documented for release in October 2015.



HNF-EP-0182, 2014, Waste Tank Summary Report for Month Ending June 30, 2014, Rev. 318, Washington River Protection Solutions, LLC, Richland, Washington.

Fig. 1. Location of Waste Management Area C in Relation to Hanford Site.

During its operational history, a number of confirmed or suspected waste release events have occurred at WMA C. These included suspected tank leaks and known unplanned releases (UPRs) from waste transfer lines and systems.

Pumping of liquid waste in preparation for removing the tanks from service began in 1976. Currently, the pumpable liquid wastes have been removed from the C Farm tanks and all tanks have been stabilized on an interim basis. Since 2003, there has been a concerted effort to retrieve the waste from the SSTs within WMA C.

As of November 2014, waste retrieval has been completed for 13 of the 16 tanks. Retrieval is underway for SST C-102, C-105, and C-111. The retrieval status will continue to evolve concurrent with the development of the PA in FY 2015.

Fig. 2 illustrates the closure concept for WMA C following tank waste retrieval. Surface facilities will be removed and retrieved single-shell tanks and accessible ancillary equipment with significant void spaces will be filled with grout. Waste transfer pipelines are also expected to be left in place. An engineered surface cover system will be placed over the tank farms and will be monitoring using existing wells.

Fig. 3 shows various pathways of possible exposure evaluated in the PA. The major pathways for contamination entering the environment are the groundwater pathway, the air pathway, and an inadvertent intruder pathway (through drill cuttings brought to the surface). The most important exposure pathway for hydrologic transport is groundwater use for drinking water, irrigation, livestock watering, and biotic transport. Under the groundwater pathway, it is assumed that moisture from rain and snowfall enters the subsurface, contacts waste, and carries dissolved contaminants through the thick heterogeneous vadose zone to the unconfined aquifer. During the compliance and post-compliance periods, a receptor is assumed to reside 100 m (328 ft) down gradient from the south eastern edge of the WMA fence line

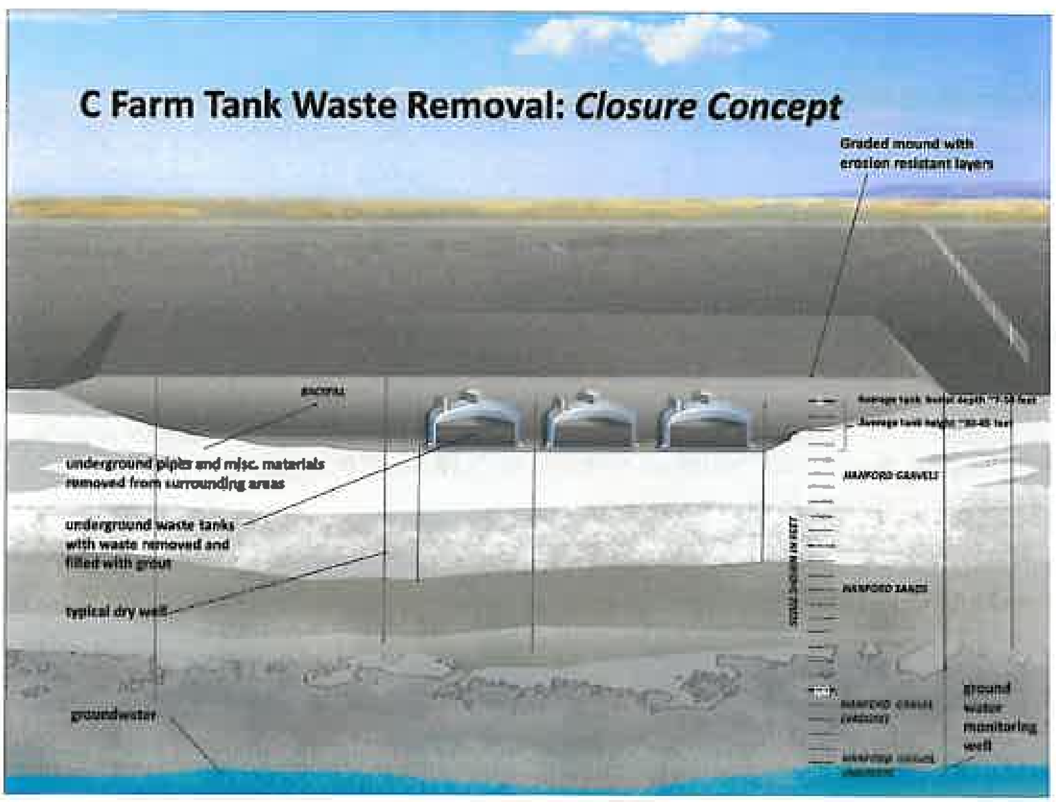


Fig. 2. Conceptual Model of Closure of WMA C.

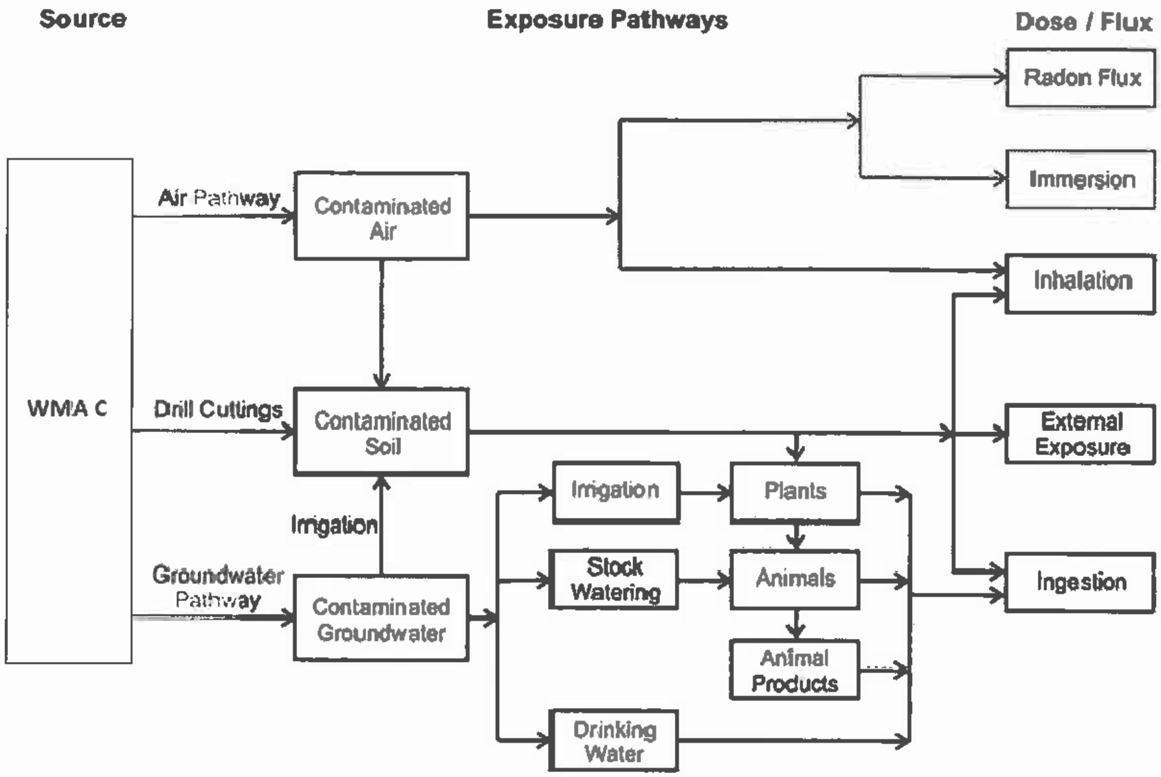


Fig. 3. Overview of the Analysis of Performance for the WMA C PA.

BACKGROUND

The WMA C PA methodology includes deterministic calculations of the estimated impacts from the proposed closure action. Impacts are calculated with the numerical models and a set of inputs and assumptions, referred to as a denominator case, developed during the PA Scoping Sessions between 2009 and 2014. A compliance case that provides the expected estimate for how the system may perform given the most current information available is under development. It is assumed that this case will provide a reasonable estimate of the expected performance. Uncertainty and sensitivity analyses using a system level model based on the GoldSim Software will also be performed to understand the importance of key input parameters on transport behavior and dose.

The source term for the denominator case analysis considers key radionculides and hazardous chemicals present in residual waste left in tanks and ancillary equipment within WMA C at closure. The inventory used in the source term model includes the current disposed inventory (as of November 2014) for 9 of the 100-series tanks and 4 200-series tanks where retrieval has been completed. A forecasted inventory for the 3 remaining 100-series tanks and ancillary equipment that have yet to be retrieved has been developed. A total of 46 radionuclides and 18 hazardous chemical are evaluated in the WMA C PA. A summary of inventories for three key constituents (technetium-99, chromium, and total uranium) adapted from inventory estimates made for the tanks and ancillary equipment [3] are provided in Table I.

TABLE I. Summary of Estimated Inventories for Selected Key Constituents for Single-Shell Tanks and Ancillary Equipment, and Pipelines in the Closed WMA C

	^{99}Tc (Ci)	**Chromium (kg)**	**Total Uranium (kg)**
Single-Shell Tanks	1.81E+00	6.58E+03	1.15E+02
Ancillary Equipment	5.45E-02	1.08E+03	2.94E+01
Pipelines	4.61E-02	9.12E+02	2.49E+01
Total	1.91E+00	8.58E+03	1.69E+02

The closed WMA C conceptual model is composed of manmade as well as natural components (Fig. 4). The manmade components of the system that influence contaminant migration include a closure surface barrier, the tank farm and ancillary equipment infrastructure, and the distribution of waste in the subsurface. The natural components of the system that influence contaminant migration are the several underlying, nearly horizontal stratigraphic layers within the vadose zone and the unconfined aquifer.

The PA modeling considered reduction of net infiltration from the presence of an engineered cover (surface barrier) over WMA C. The surface barrier is assumed to remain intact and allow only negligible amounts of net infiltration for the first 500 years (i.e., 2020 to 2520), coinciding with an estimated 500-yr barrier design life, which includes a 100-yr institutional control time period.

For the purpose of assessing the long-term performance, a closure date of 2020 is assumed for WMA C. In the post-closure assessment, four time periods are considered as presented in Table II:

- A 100-year institutional control period when the engineered surface cover (overlying WMA C) are working to their full barrier capability resulting in 0.5 mm/yr recharge rate under the base of WMA C

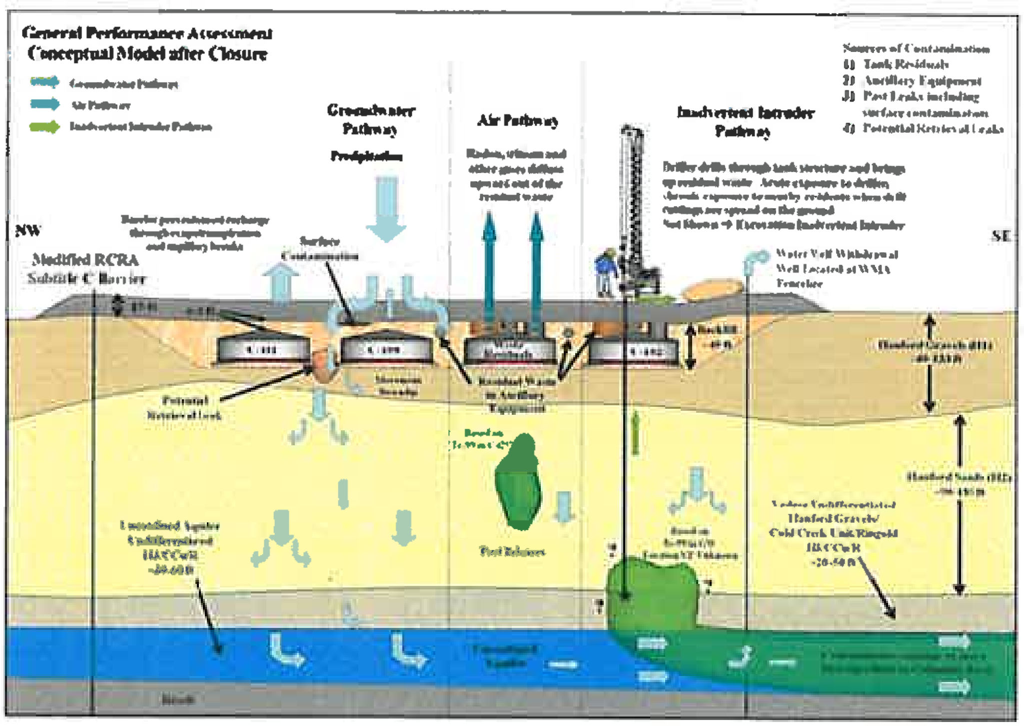


Fig. 4. Schematic Conceptual Representation of the WMA C Site and Various Pathways.

- An additional time period of 400 years after the institutional control period during which the full barrier capability results in 0.5 mm/yr recharge rate under the base of WMA C

- A time period after 500 years after closure during which the surface cover barrier function is assumed to be fully degraded at the start of the time period (assuming a design life of 500 years)

- The post-compliance period (beyond 1,000 years) up to 10,000 years for the purpose of evaluating uncertainty and sensitivity on dose estimates. Maximum impacts from long-lived mobile radionuclide and hazardous chemicals occur within this time period.

Net infiltration (recharge) estimates for each of the time periods [5] is presented in Table II. The recharge rates can vary spatially within each time period depending upon the type of vegetation or state of engineered barrier.

TABLE II. Timeline Considered for Representing the Evolution of WMA C.

			Recharge on Surface (mm/yr [in./yr])			
Phase	**Conditions**	**Time frame (yrs)**	**Natural Vegetation**	**Tank Farm Disturbed Surface**	**Non-Tank Farm Disturbed Surface***	**Surface Barrier**
Pre-Operations	Before construction of WMA C	Prior 1944	3.5 [0.14]	NP	NP	NP
Operations	Current Conditions During Operations at WMA C	1944-2020	3.5 [0.14]	100 [3.9]	22 [0.87]/63 [2.5]	NP
First 100-years Post-Closure	Post-Closure During Institutional Control Period	2020 -2120	3.5 [0.14]	NP	3.5 [0.14]	0.5 [0.02]
Early Post-Closure (100 to 500 years)	Post-Institutional Control Period to End of 500-yr Barrier Design Life	2120 - 2420	3.5 [0.14]	NP	3.5 [0.14]	0.5 [0.02]
Late Post-Closure (after 500 years)	Post-Barrier Design Life	2420 - 12020	3.5 [0.14]	NP	3.5 [0.14]	3.5 [0.14]

NP - Not present

Based on the conceptual models for different pathways, numerical models were developed to estimate the contaminant concentrations within water, air, or soil as a function of time. A three-dimensional flow and transport model was developed using the Subsurface Transport Over Multiple Phases code developed by Pacific Northwest National Laboratory [5] to evaluate the impact to the environment from the groundwater pathway. The model assumed that infiltration of moisture from precipitation eventually enters the facility. However, most of the moisture is diverted around WMA C during operations and for the first 500 years after closure. Contaminants, based on their relative inventories associated with different tanks and ancillary equipment, are released into the vadose zone by contact with recharge water. The infiltrating moisture, along with contaminants, travels through the vadose zone with the contaminant transport times influenced by the equilibrium sorption characteristics (determined by the distribution coefficient [K_d]).

In the denominator case, a diffusion controlled release from the grouted tanks and advection controlled release from the pipelines along with equilibrium sorption-desorption processes (i.e., K_d control) were implemented. In this case, the residual waste layer is conceptualized to be located at the top of the grout at the bottom of each tank. The combined minimum thickness of concrete and grout layer under the residual waste is 20.3 cm (~8 inches). This is considered to be a physical barrier to release of contaminants to the underlying vadose zone. While the grout/concrete layer is intact, only diffusive transport of contaminants across this layer is considered. When this layer is degraded, both advective and diffusive transport to the vadose zone can occur.

The diffusion coefficients of contaminant through the grout/concrete layer are derived from laboratory leaching experiments [5,7] that range from 10^{-9} to 10^{-14} cm^2/s. These values are implemented for the various cases being evaluated for the PA, with the denominator case using the highest value of 10^{-9} cm^2/s. The diffusive area considered is taken to be the base area of the structure being modeled (tank or CR-vault). For the pipelines, the area is based on the assessed area of the tank farm where pipelines are generally present. It is currently defined by a square of length of 164 m and covers the majority of the WMA C area.

GROUNDWATER PATHWAY RESULTS

Fig. 5 presents an example of the spatial distribution of technetium-99 estimated from an inventory release of 70.7 GBq (1.91 Ci) within all waste residual with and without pipelines at the end of 1,000 years of simulation in the denominator case. In this case, the technetium travels unretarded through the vadose zone and the saturated zone but does reach the underlying unconfined aquifer below the site within the 1000-yr compliance period.

Fig. 6 presents the groundwater breakthrough curves of selected constituent releases from all single-shell tanks and ancillary over the 10,000-year simulation period at the points of calculation (100 m [328 ft] downgradient of the WMA C). Only two of constituents, technetium-99 and chromium, which move unretarded through the vadose zone and groundwater, show breakthrough at the points of calculation. Uranium with an assumed K_d value greater than zero (K_d = 0.6 mL/g for sand dominated units) begins to arrive at the points of calculation near the end of the 10,000 year period of analysis. Technitium-99 reaches a peak value of about 11 pCi/l at about year 6300 (about 4300 years after closure), whereas the peak value for chromium of 1 mg/l occurs at about year 5100. The differences in the timing of these peaks reflect about the mobility of chromium (K_d = 0.0 ml/g) and technetium-99 (K_d = 1.0 ml/g) assumed in the diffusion-controlled releases through the concrete and grout at the bottom of each single-shell tank. Results for these key constituents of concern are below their respective drinking water standards [8]

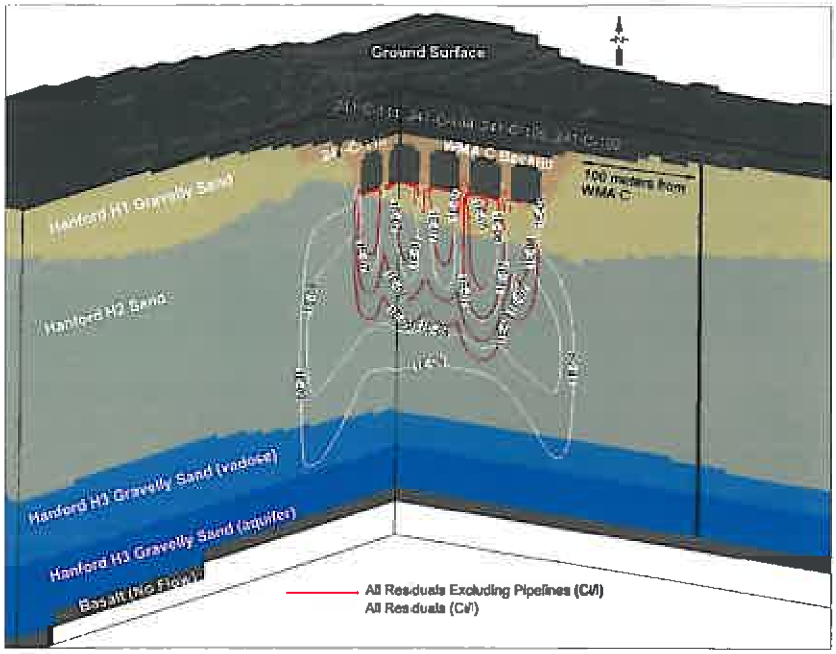


Fig. 5. Extent of Transport of the Most Mobile Radionuclides Such as Technetium-99 (K_d = 0 mL/g) in the Vadose Zone at the End of the 1,000-year Compliance Period for an Inventory Release of 70.7GBq (1.91 Ci) from All Residuals With and Without Pipelines (See Inventory Breakdown in Table I). Note: 1 Ci/L = 37 GBq/L.

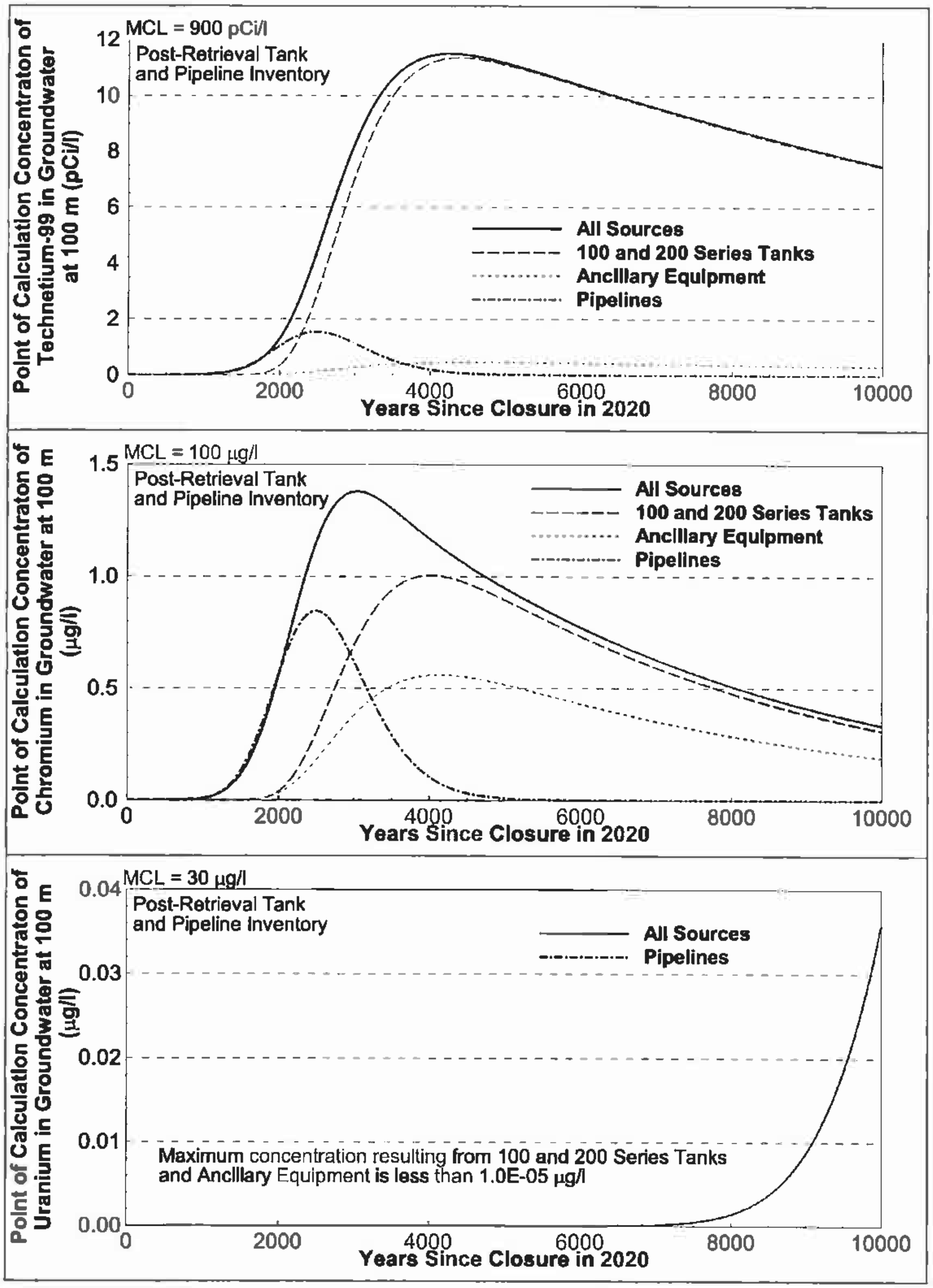


Fig. 6. Maximum Predicted Groundwater Concentration for Selected Constituents (^{99}Tc, Chromium, and Total Uranium) at 100 m (328 ft) Downgradient from WMA C Through the End of the Post-Closure Period. (Note: 1 pCi/L = 0.037 Bq/L)

Besides the denominator case, several other additional sensitivity cases are being conducted to evaluate the effect of changes in key parameter values in the PA analysis. These include selected cases that examine the effect of:

- The timing of potential future tank degradation on contaminant releases and resulting groundwater impacts
- Alternative time-varying recharge rates the arrival of groundwater breakthrough curves downgradient of WMA C
- Increases in estimated residual inventories on the magnitude of predicted concentrations downgradient of WMA C

AIR PATHWAYS RESULTS

Under the atmospheric pathway, for a limited number of radionuclides that can partition into the gas phase from dissolved phase (e.g., carbon-14, hydrogen-3, and iodine-129), a conservative one-dimensional model is performed to estimate diffusive release from the WMA C into the atmosphere across the modified RCRA [4]-compliant closure cover (Fig. 4). The concentration in air at the point of calculation is negligibly small for all three radionuclides. The concentration of tritium is highest (2E-05 pCi/L) at the start of the closure period but declines quickly due to short half-life. The concentration of ^{14}C and ^{129}I remain negligibly small throughout the simulated time frame. The atmospheric pathway dose calculations are also negligibly small.

The radon flux at the surface of the WMA C facility is estimated for every source term separately. The highest flux occurs from C-301 tank source with a peak value of 6.8E-04 pCi/m^2/sec. This value is much lower compared to the 20 pCi/m^2/sec performance objective. Tank C-301 has one of the highest initial concentrations of ^{226}Ra and ^{234}U due to combination of higher inventory and smaller residual volume compared to other tanks and ancillary equipment. Additionally, because the cross-sectional area of the C-301 tank is small (similar to the 200-series tank), it leads to high diffusive flux per unit surface area.

INADVERTENT INTRUDER RESULTS

Under the intruder scenarios, a well is drilled through the residual waste in the closed WMA C all the way to the water table. The contamination is then brought to the surface as part of the drill cuttings where it can cause human exposure (Fig. 4). Exposure to this contamination is evaluated using an acute well drilling and three chronic inadvertent intruder (commercial farm, rural pasture, and suburban garden) scenarios. Although the likelihood of an inadvertent intrusion at WMA C is very small in the foreseeable future, for the purpose of compliance calculations, passive and active institutional controls are assumed to be ineffective in preventing temporary intrusion after 100 years following closure. In other words, loss of institutional controls is assumed after 100 years following closure and peak dose is evaluated assuming inadvertent intrusion occurs immediately after the loss of institutional controls.

A summary of intruder results at 100 and 500 years post-closure for all inadvertent human intrusion exposure scenarios and sources in WMA C is provided in Table IV. Acute exposure scenario dose plots for tanks C-111 and C-112 are presented in Fig. 7 as examples while chronic scenario dose plots for tanks C-111 and C-112 are presented in Fig. 8 to show the general dose trends for the various scenarios analyzed. The results from tanks C-111 and C-112 are presented because examination of the tank inventories shows that the highest concentrations of ^{137}Cs and ^{90}Sr (the main contributors to intrusion doses) are found in these tanks.

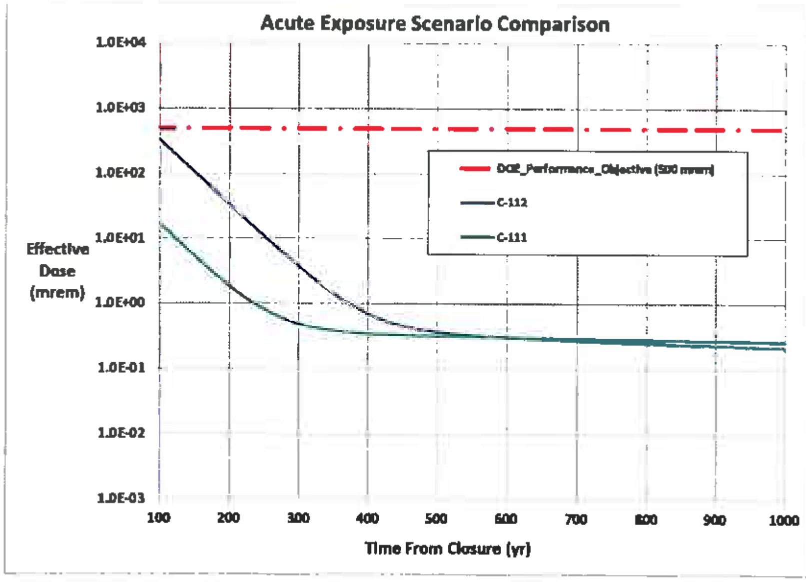


Fig. 7. Effective Dose to the Intruder versus Time of Intrusion after Site Closure for Acute Well driller Scenarios

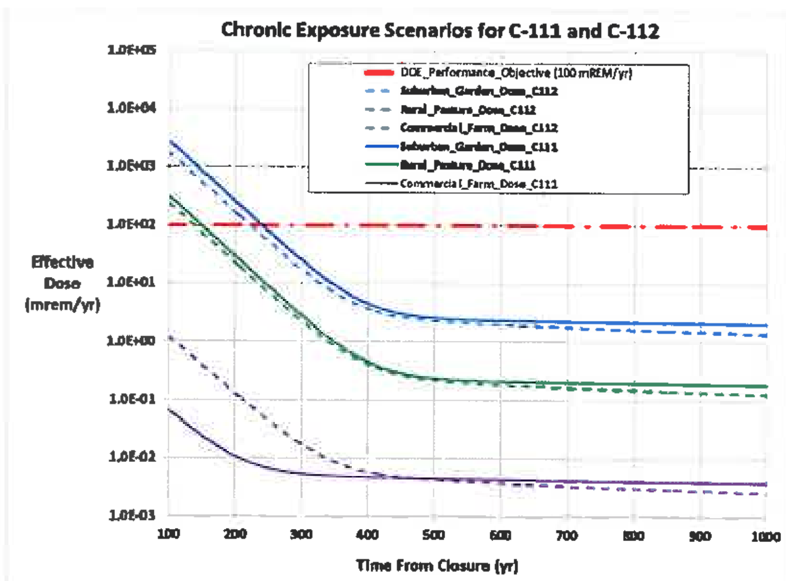


Fig. 8. Effective Dose to the Intruder versus Time of Intrusion after Site Closure for the Chronic Scenarios.

Evaluation of the results presented in Table IV show that doses from the well driller scenario are well below the 500 mrem performance objective for acute exposure at 100 years post closure time. Results also show that doses from the rural pasture and commercial farm scenarios are also well below the 100 mrem/yr performance objective for chronic exposure at 100 years post-closure. Exceptions include doses for the rural pasture scenario for tanks C-111, C-112, and C-301.

TABLE IV. Summary of Denominator Case Doses for the Hypothetical Inadvertent Human Intruder Exposure Scenarios in Waste Management Area C at 100 Years and 500 Years After Closure.

Source	Well Driller Acute Dose (mrem)		Commercial Farm Chronic Dose (mrem/yr)		Rural Pasture Chronic Dose (mrem/yr)		Suburban Garden Chronic Dose (mrem/yr)	
	100 yr	500 yr	100 yr	500 yr	100 yr	500 yr	100 yr	500 yr
241-C-101	4.654	0.1222	0.03458	0.003187	16.05	0.1546	***133.8***	1.729
241-C-102	2.721	0.8504	0.0197	0.01186	2.201	0.5739	19.13	6.431
241-C-103	15.4	0.08315	0.05438	0.00106	32.39	0.05373	***271.7***	0.591
241-C-104	13.7	0.1314	0.03104	0.000878	13.68	0.0461	***112.7***	0.4977
241-C-105	34.53	0.2408	0.1304	0.003379	49.05	0.1713	***399.4***	2.007
241-C-106	32.76	1.687	0.1314	0.01079	***206.4***	0.4339	***1789***	3.639
241-C-107	32.86	1.856	0.1471	0.02428	***230.5***	1.167	***2007***	12.82
241-C-108	1.555	0.005251	0.00637	5.40E-05	4.805	0.003331	40.7	0.03666
241-C-109	1.966	0.008275	0.004703	6.91E-05	9.082	0.003985	78.87	0.04322
241-C-110	0.8983	0.007219	0.002233	6.84E-05	1.23	0.003722	10.29	0.04806
241-C-111	16.91	0.3199	0.06687	0.004429	***313.6***	0.2351	**2750**	2.566
241-C-112	327.7	0.3664	1.214	0.004207	***237.5***	0.2147	**1773**	2.266
241-C-201	6.54	3.086	0.04971	0.03715	13.05	1.794	**117.1**	20.19
241-C-202	6.424	2.715	0.04554	0.03286	22.91	1.589	**203.2**	17.89
241-C-203	4.796	0.1401	0.01312	0.00121	10.32	0.06157	88.02	0.6662
241-C-204	2.323	0.05643	0.005974	0.000192	6.707	0.01003	57.63	0.1037
241-C-301	8.25	0.7296	0.2047	0.05013	***175.6***	2.389	***1514***	26.24
CR-Vault	8.278	0.7317	0.067	0.0164	57.32	0.7816	***494.3***	8.588
Pipelines	8.265	0.7306	0.000342	8.38E-05	0.2931	0.003993	2.527	0.04387

As expected, maximum impacts are realized from the chronic suburban garden scenario. For this scenario, doses at 100 years post-closure exceed the chronic dose performance objective of 100 mrem/yr in several tanks including C-101, C-103, C-104, C-105, C-106, C-107, C-111, C-112, C-201, C-202, C-301 catch tank, and the CR-Vaults. The highest doses for this scenario are associated with intrusion into waste inventories from tanks C-106, C-107, C-111, C-112, and the C-301 catch tank. Examples of chronic scenario doses for tanks C-111 and C-112 (Fig. 8) illustrate general trends which indicate that doses from all facilities are well below the performance objective of 100 mrem/yr for chronic exposure well within 250 years after closure.

CONCLUSIONS

Results of the preliminary analyses for the groundwater pathway conducted so far show that the proposed closure of WMA C tanks and ancillary equipment is expected to be well below the performance objectives during the 1,000-yr post-closure period of compliance. In the denominator case, none of the major risk drivers (^{99}Tc, chromium, and uranium) from WMA C reach groundwater within the compliance period (1,000 years post-closure) with any appreciable concentration. The peak time for chromium occurs around 3,000 years after closure while that for ^{99}Tc occurs around 4,500 years after closure. The delay in ^{99}Tc peak is attributed to the retardation (from sorption) within the grout/concrete layer at the base of the tank. The uranium breakthrough time at the point of calculation is significantly delayed (> 4,000 years after closure) due to additional sorption in the natural system. The uranium breakthrough from pipeline source occurs earlier due to advection-dominated releases, while the breakthrough times from the tank sources is delayed beyond 8,000 years due to diffusive releases from the tank residuals. The peak times for uranium occur beyond the simulated timeframe.

For air pathway analysis of the denominator case inventory, the contribution from air pathway is negligibly small with only three potential volatiles – tritium (^{3}H), ^{14}C, and ^{129}I – present in the residual inventory. Due to small concentrations and their relative fractionation from the dissolved phase to the gas phase the concentrations at the point of calculation remain negligible (<1E-05 pCi/L), leading to negligible dose. Diffusive gas-phase release of radon is calculated separately from each source and evaluated above the source area (e.g., tank area). The radon flux varies among the sources analyzed but remains negligibly small. The peak flux resulting from C-301 tank is less than 0.001 pCi/m^2/sec.

For the hypothetical inadvertent intruder analyses, one acute and three chronic scenarios were considered. Calculations were performed using the denominator case inventory for each source separately. The effective dose resulting from the acute well driller scenario met the 500 mrem performance measure for acute exposure during the post-institutional control period.

The effective dose resulting from chronic suburban garden scenario was found to be the highest among the scenarios analyzed. For the majority of the tanks, doses exceeded the 100-mrem/yr performance measure for chronic exposure within the first 200-year period following institutional control. The major dose drivers are ^{90}Sr and ^{137}Cs within the first 200 to 300 years after closure, with minor contributions from ^{241}Am and ^{239}Pu. Americium-241 and ^{239}Pu contribute the majority of the dose after 300 years, and in the cases of the commercial farm and well driller scenarios, most of the dose after 200 years. Note that this calculation does not consider the likelihood of inadvertent intrusion through the tanks and possibility of suburban garden near the WMA C area.

This preliminary evaluation of performance of a closed WMA C has used projected estimates of volumes and inventories for selected tanks based on either Hanford Tank Waste Operations Simulator or BBI estimates. At the time this analysis was performed, calculations were not able to account for:

- Final inventories for wastes left in three retrieved SSTs (C-101, C-107 and C-112) that will be developed from waste residual sampling and analyses
- Final volumes and inventories for waste left in three SSTs (C-102, C-105 and C-111) that are in the process of being retrieved
- Final volumes and inventories for waste left in the CR-vault tanks, the C-301 catch tank, and other ancillary equipment where retrieval has not been initiated.

Based on progress to date with un-retrieved tanks, it is anticipated that final volumes for the unretrieved tanks may be above final volumes assumed in the set of analyses presented in this submittal. In FY 2015, we anticipate evaluating an additional sensitivity case that will examine, as bounding inventory case, the volume and concentration for waste remaining in these unretrieved tanks based on the BBI at the time that this information is finalized for the first version of the PA.

Eventually, once retrieval of these SSTs and other ancillary equipment has been completed and final inventories have been estimated based on waste residual sampling and analysis, the impacts from these final volumes and inventories will need to be evaluated. Analysis of final closure volumes and inventories will not be included in the initial version of the PA that will be released at the end of FY 2015 but will be considered in the next iteration of the PA.

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