DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

Release Stamp

DATE:
Jul 09,2020
HANFORD RELEASE

1. **Doc No:** RPP-CALC-63600 **Rev.** 00

2. **Title:**
Calculation of Groundwater Impacts from Hazardous Chemicals in Residual Wastes Left in Tanks and Ancillary Equipment at Waste Management Area A-AX

3. **Project Number:** ☐N/A
T2C25

4. **Design Verification Required:**
☐Yes ☒No

5. **USQ Number:** ☒ N/A
RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type:
public

7. **Approvals**

Title	**Name**	**Signature**	**Date**
Clearance Review	Raymer, Julia R	*Raymer, Julia R*	07/09/2020
Checker	Lee, Kearn (Pat)	*Lee, Kearn (Pat)*	06/16/2020
Document Control Approval	Alvarez, Efren	*Alvarez, Efren*	07/09/2020
Originator	Watson, David (Dj) J	*Watson, David (Dj) J*	06/08/2020
Quality Assurance	Lungu, Cris C	*Lungu, Cris C*	06/08/2020
Responsible Manager	Rutland, Paul L	*Rutland, Paul L*	06/17/2020

8. **Description of Change and Justification**

Initial issue

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☒N/A	b. **Related Systems** ☒N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A

11. **Impacted Documents – Engineering** ☒N/A

Document Number	**Rev.**	**Title**

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	**Rev.**	**Title**
RPP-ENV-62206	00	Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington

14. **Distribution**

Name	**Organization**
Bergeron, Marcel P	CLOSURE & INTERIM MEASURES
Childress, Ryan D	CLOSURE & INTERIM MEASURES
Lee, Kearn (Pat)	CLOSURE & INTERIM MEASURES
Rutland, Paul L	CLOSURE & INTERIM MEASURES
Singleton, Kristin M	CLOSURE & INTERIM MEASURES

INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part I: Background Information

Title: Calculation of Groundwater Impacts from Hazardous Chemicals in Residual Wastes Left in Tanks and Ancillary Equipment at Waste Management Area A-AX

Publish to OSTI? ☐ Yes ☑ No

Information Category:

☐ Abstract	☐ Journal Article	☐ Summary
☐ Internet	☐ Visual Aid	☐ Software
☐ Full Paper	☑ Report	☐ Other

	Yes	NA
Trademark/Copyright “Right to Use” Information or Permission Documentation	☐	☑

Document Number: RPP-CALC-63600 Revision 0

Date: June 2020

Author: Watson, David (Dj) J

Part II: External/Public Presentation Information

Conference Name:

Sponsoring Organization(s): DOE-ORP

Date of Conference:

Conference Location:

Will Material be Handed Out? ☐ Yes ☑ No

Will Information be Published? ☐ Yes ☑ No

(If Yes, attach copy of Conference format instructions/guidance.)

Part III: WRPS Document Originator Checklist

Description	*Yes*	*N/A*	*Print/Sign/Date*
Information Product meets requirements in TFC-BSM-AD-C-01?	☐	☑	
Document Release Criteria in TFC-ENG-DESIGN-C-25 completed? (Attach checklist)	☐	☑	
If product contains pictures, safety review completed?	☐	☑	

Part IV: WRPS Internal Review

Function	*Organization*	*Date*	*Print Name/Signature/Date*
Subject Matter Expert	WRPS		Watson, David (Dj) J Approved via att. IDMS data file.
Responsible Manager	WRPS		Rutland, Paul L Approved via att. IDMS data file.
Other:			

Part V: IRM Clearance Services Review

Description	*Yes*	*No*	*Print Name/Signature*
Document Contains Classified Information?	☐	☑	If Answer is “Yes,” ADC Approval Required Print Name/Signature/Date
Document Contains Information Restricted by DOE Operational Security Guidelines?	☐	☑	Reviewer Signature: Print Name/Signature/Date
Document is Subject to Release Restrictions? *If the answer is “Yes,” please mark category at right and describe limitation or responsible organization below:*	☐	☑	Document contains: ☐ Applied Technology ☐ Personal/Private ☐ Proprietary ☐ Patentable Info. ☐ Predecisional Info. ☐ Restricted by Operational Security Guidelines ☐ Other (Specify) ☐ Protected CRADA ☐ Export Controlled ☐ Procurement – Sensitive ☐ OUO ☐ UCNI
Additional Comments from Information Clearance Specialist Review?	☐	☑	Information Clearance Specialist Approval APPROVED By Julia Raymer at 2:01 pm, Jul 06, 2020 Print Name/Signature/Date

When IRM Clearance Review is Complete – Return to WRPS Originator for Final Signature Routing (Part VI)

INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part VI: Final Review and Approvals

Description	*Approved for Release*		*Print Name/Signature*
	Yes	*N/A*	
WRPS External Affairs	☑	☐	Approved via att. IDMS data files.
WRPS Office of Chief Counsel	☑	☐	Approved via att. IDMS data files.
DOE – ORP Public Affairs/Communications	☑	☐	Approved via att. IDMS data files.
Other: ORP SME & OCC	☑	☐	Approved via att. IDMS data files.
Other:	☐	☐	

Comments Required for WRPS-Indicate Purpose of Document:

This document reports the results of calculations of cancer risks and non-cancer hazards to a receptor using groundwater at both the Waste Management Area (WMA) A-AX fenceline and 100 m from the closed WMA A-AX under the U.S. Environmental Protection Agency's residential tap water scenario.

This document supports the forthcoming "Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington".

APPROVED
By Julia Raymer at 2:06 pm, Jul 06, 2020

Approved for Public Release;
Further Dissemination Unlimited

Information Release Station

Was/Is Information Product Approved for Release? ☑ Yes ☐ No

If Yes, what is the Level of Releaser? ☑ Public/Unrestricted ☐ Other (Specify) ______

Date Information Product Stamped/Marked for Release: 07/06/2020

Was/Is Information Product Transferred to OSTI? ☐ Yes ☑ No

Forward Copies of Completed Form to WRPS Originator

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        Thank you, Julia Raymer, Information Clearance</comments>
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RPP-CALC-63600
Revision 0

Calculation of Groundwater Impacts from Hazardous Chemicals in Residual Wastes Left in Tanks and Ancillary Equipment at Waste Management Area A-AX

Prepared by:

D.J. Watson
Washington River Protection Solutions, LLC

Date Published
December 2019

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

ENVIRONMENTAL MODEL CALCULATION COVER PAGE

SECTION 1: COMPLETED BY RESPONSIBLE MANAGER OR DESIGNEE

Rev. 0
RELEASE/ISSUE

Project: Waste Management Area A-AX Performance Assessment

Date: 9/26/2019

Calculation Title and Description: Calculation of Groundwater Impacts from Hazardous Chemicals in Residual Wastes Left in Tanks and Ancillary Equipment at Waste Management Area A-AX

SECTION 2: COMPLETED BY PREPARER

Calculation No.: RPP-CALC-63600 Revision No.: 0

Revision History

ADD ROW

Revision No.	**Description**	**Date**	**Affected Pages**
Rev. 0	Initial issue	9/26/2019	

D

SECTION 3: COMPLETED BY RESPONSIBLE MANAGER OR DESIGNEE

Document Control

1. Is document intended to be controlled within SmartPlant? ☒ Yes ☐ No
2. Does document contain scientific and technical information intended for public use? ☐ Yes ☒ No
3. Does document contain controlled-use information? ☐ Yes ☒ No

SECTION 4: TRAINING AND SOFTWARE INSTALLATION APPROVAL *(COMPLETED PRIOR TO PERFORMING CALCULATION)*

Modeler-Required Training Completed:

Training Coordinator:

Marcel P. Bergeron	Principal Scientist		9/30/2019
Print First and Last Name	*Position*	*Signature*	*Date*

Software Installation and Checkout Certified:

Integration Lead:

William E. Nichols	CHPRC Modeling Team Ldr		9/30/2019
Print First and Last Name	*Position*	*Signature*	*Date*

SECTION 5: DOCUMENT REVIEW AND APPROVAL

Preparer:

David J. Watson	Scientist		9/26/2019
Print First and Last Name	*Position*	*Signature*	*Date*

Checker:

Wei Zhou	Senior Nuclear Engineer		9/26/2019
Print First and Last Name	*Position*	*Signature*	*Date*

Senior Reviewer:

Matt Kozak	Principal Engineer		11/13/2019
Print First and Last Name	*Position*	*Signature*	*Date*

Responsible Manager or Designee:

Bob Hiergesell	Senior Scientist	R Hiergesell	11/15/19
Print First and Last Name	*Position*	*Signature*	*Date*

CHECKER LOG FOR SYSTEM MODELS

Project and Environmental Model Calculation Specific Information:

Project: Waste Management Area A-AX Performance Assessment

Responsible Manager or Designee, and Position: Bob Hiergesell, Senior Scientist

Originating Group or Department: Closure and Interim Measures Date: 9/26/2019

Environmental Model Calculation File Report and Revision No.: RPP-CALC-63600, Rev. 0

Environmental Model Calculation File Title: a_ax v1.0_20190813

Check: Environmental Model Calculation File Document Elements

	List where Information is Described *(EMCF Section Number)*	Is the Description Correct and Sufficient?			Checker Signature
		Yes	No	If No, describe deficiency:	
Purpose	1.0	●	○		
Calculation Approach	3.4	●	○		
Assumptions	4.1	●	○		
Inputs *(reference detailed checklist below as well)*	4.2	●	○		
Equations used	3.3	●	○		
Conclusions	7.1	●	○		
References	7.2	●	○		

Check: Controlled Software Use

	List where Information is Described *(EMCF Section Number)*	Is the Criteria Met?			Checker Signature
		Yes	No	If No, describe deficiency:	
Software used in the calculation is appropriate for application	Section 5.1	●	○		
Software use is approved and properly validated in accordance with approved software management plan	5.2	●	○		
Software use is properly documented	5.3	●	○		
Verify data was input correctly to approved software or spreadsheets	Yes	●	○		
If a spreadsheet is used, verify inputs/outputs of calculation(s) to ensure accuracy	No spreadsheet is used.	●	○	No spreadsheet is used.	

Check: Perform Calculation to Verify Free of Errors

	Describe how calculation was performed	List any discrepancies encountered *(If none, enter "None")*	Checker Signature
Perform the environmental model calculation as described to verify it is free of errors	running GoldSim model file a_ax v1.0_20190813_Tap_Water Scenario.gsm	None	

CHECKER LOG FOR SYSTEM MODELS (Continued)

Check: Process Model Parameterization *(Specify Values and Units in Each Column)*

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Simulation duration	yes.	yes.	yes.
Simulation time step control	No because it is not necessary	Not applicable.	Not applicable.
Simulated chemical list	yes.	yes.	yes.
Simulated radionuclides list	No because radionuclides are not needed.	Not applicable.	Not applicable.
External model components identified and documented or referenced	No external model components are needed.	Not applicable.	Not applicable.
External model linkages *(dynamic link libraries, etc.)* checked	Not applicable.	Not applicable.	Not applicable.
If model is probabilistic, stochastic distributions are defined and consistent	Not probabilistic.	Not applicable.	Not applicable.
Input units are declared and of correct dimensionality	yes.	yes	yes
Equations used in the model file are presented in EMCF and consistent	yes	yes	yes

Check: Further Checks *(Record additional checks performed and results)*

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Inventory: Radiological Decay Correction. Does the inventory *(source term)* include radionuclides, and if so, is it decay-corrected to the appropriate date for inclusion as a source?	yes.	yes.	yes.
Inventory: Mass Balance. Is mass balance of inventory maintained in system model calculation(s)?	Mass balance of the same model was performed before but is not needed in this EMCF.	Not applicable.	Not applicable.

CHECKER LOG FOR SYSTEM MODELS

Project and Environmental Model Calculation Specific Information:

Project: Waste Management Area A-AX Performance Assessment

Responsible Manager or Designee, and Position: Bob, Hiergesell, Senior Scientist

Originating Group or Department: Closure and Interim Measures

Date: 02/24/2020

Environmental Model Calculation File Report and Revision No.: RPP-CALC-63600, Rev. 0

Environmental Model Calculation File Title: Calculation of Groundwater Impacts from Hazardous Chemic

Check: Environmental Model Calculation File Document Elements

	List where Information is Described *(EMCF Section Number)*	Is the Description Correct and Sufficient?			Checker Signature
		Yes	No	If No, describe deficiency:	
Purpose	1.0	●	○		
Calculation Approach	3.4	●	○		
Assumptions	4.1	●	○		
Inputs *(reference detailed checklist below as well)*	4.2	●	○		
Equations used	3.3	●	○		
Conclusions	7.1	●	○		
References	7.2	●	○		

Check: Controlled Software Use

	List where Information is Described *(EMCF Section Number)*	Is the Criteria Met?			Checker Signature
		Yes	No	If No, describe deficiency:	
Software used in the calculation is appropriate for application	Section 5.1	●	○		
Software use is approved and properly validated in accordance with approved software management plan	5.2	●	○		
Software use is properly documented	5.3	●	○		
Verify data was input correctly to approved software or spreadsheets	Yes (see attached)	●	○		
If a spreadsheet is used, verify inputs/outputs of calculation(s) to ensure accuracy	No spreadsheet was used.	●	○		

Check: Perform Calculation to Verify Free of Errors

	Describe how calculation was performed	List any discrepancies encountered *(If none, enter "None")*	Checker Signature
Perform the environmental model calculation as described to verify it is free of errors	Verification of changes, replication of changes and runs.	None	

CHECKER LOG FOR SYSTEM MODELS (Continued)

Check: Process Model Parameterization *(Specify Values and Units in Each Column)*

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Simulation duration	yes (via results)	not applicable	yes
Simulation time step control	No because it is not necessary	Not applicable	yes
Simulated chemical list	Yes (via Results)	yes	yes
Simulated radionuclides list	not applicable, chemicals only	not applicable	not applicable
External model components identified and documented or referenced	No external model components	not applicable	not applicable
External model linkages *(dynamic link libraries, etc.)* checked	No external model linkages	not applicable	not applicable
If model is probabilistic, stochastic distributions are defined and consistent	Not probabilistic	not applicable	not applicable
Input units are declared and of correct dimensionality	Yes	Yes	Yes
Equations used in the model file are presented in EMCF and consistent	Yes (Section 3)		

Check: Further Checks *(Record additional checks performed and results)*

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Inventory: Radiological Decay Correction. Does the inventory *(source term)* include radionuclides, and if so, is it decay-corrected to the appropriate date for inclusion as a source?	Yes. The inventory is not listed but is documented through a reference to a data package and previous calculation.	No. Inventory was checked for a previous calculation and was not repeated for this assessment. Did confirm that inventory was not changed from previous work.	Not applicable.
Inventory: Mass Balance. Is mass balance of inventory maintained in system model calculation(s)?	Mass balance was checked during the development of the model that is used in this calculation. It was not repeated.	No. Mass balance was checked for a previous calculation and was not repeated for this assessment. Did confirm that model changes should not impact the mass balance assessment from previous work.	Not applicable.
See attached			

2/24/2022

Checker Log Addendum

This check applies to the sensitivity calculations only. The model files and results related to models listed in Table 6-1 were reviewed for this check. All other checking of the source models was done previously and was not repeated for this work. Checking of sensitivity cases verified that any model changes were correct and necessary to perform the analysis.

On the checker log, elements of the check pertaining to **Environmental Model Calculation File Document Elements** and **Controlled Software Use** are copied from the previous work.

- Confirmed Table 6-1 listed correct model file names. Each was saved with a date 2/20/2020.
- EMCF-62538.gsm dated 1/30/2020 @ 9:45 AM
    - Confirmed Total_Chem_Conc_100m_A was correctly implemented (sum of 100-m groundwater concentrations from all A Farm residual waste sources)
    - Confirmed A_NO2_100m_Conc and A_NO2_100m_Conc_By_Source were linked to correct elements and labeled correctly.
    - Confirmed Total_Chem_Conc_100m_AX was correctly implemented (sum of 100-m groundwater concentrations from all AX Farm residual waste sources)
    - Confirmed AX_NO2_100m_Conc and AX_NO2_100m_Conc_By_Source were linked to correct elements and labeled correctly.
    - Reviewed GoldSim version report relative to last versioning (v1.004 on Jan 27, 2020). Logged changes are consistent with a run model with the stated changes listed in Section 6.1 of the report.
- a_ax v1.0_20190408_INV_0_1_2(b).gsm dated 1/30/2020 @ 9:49 AM
    - Confirmed Total_Chem_Conc_100m_A was correctly implemented (sum of 100-m groundwater concentrations from all A Farm residual waste sources)
    - Confirmed A_NO2_100m_Conc and A_NO2_100m_Conc_By_Source were linked to correct elements and labeled correctly. Label says NO3 but correctly linked to NO2. (disposition: fixed in model version appended with "minor_fix").
    - Confirmed Total_Chem_Conc_100m_AX was correctly implemented (sum of 100-m groundwater concentrations from all AX Farm residual waste sources)
    - Confirmed AX_NO2_100m_Conc and AX_NO2_100m_Conc_By_Source were linked to correct elements and labeled correctly.
    - Reviewed GoldSim version report relative to last versioning (v1.003 on Jan 27, 2020). Logged changes are consistent with a run model with the stated changes listed in Section 6.1 of the report.
- a_ax v1.0_20190408_GRT_BM_TS.gsm dated 2/3/2020 @ 10:19 AM
    - Confirmed Total_Chem_Conc_100m_A was correctly implemented (sum of 100-m groundwater concentrations from all A Farm residual waste sources)
    - Confirmed A_NO2_100m_Conc, A_Tc_100m_Conc, and A_NO2_100m_Conc_By_Source were linked to correct elements and labeled correctly. The time history result for AX ancillary equipment in AX_NO2_100m_Conc_by_Source is incorrectly linked to AX104 results instead of the AX ancillary equipment results. (disposition: fixed in model version appended with "minor_fix").
    - Confirmed Total_Chem_Conc_100m_AX was correctly implemented (sum of 100-m groundwater concentrations from all AX Farm residual waste sources)

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Checker Log Addendum

  - Confirmed AX_NO2_100m_Conc, AX_Tc_100m_Conc, and AX_NO2_100m_Conc_By_Source were linked to correct elements and labeled correctly.
  - Reviewed GoldSim version report relative to last versioning (v1.003 on Jan 27, 2020). Logged changes are consistent with a run model with the stated changes listed in Section 6.1 of the report.
- Figure 7-24: Visually compared graphic to GoldSim model with results. The two appear equivalent. Also confirmed peak values and peak times describing figure.
- Table 7-9: Compared tabulated values to GoldSim model with results. All are acceptable.
- Figure 7-25: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-26: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-27: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-28: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Table 4-10: Compared entries copied from source. Entries were equivalent.
- Figure 7-29: Visually compared graphic to GoldSim model with results. The two appear equivalent. Also confirmed peak values and peak times describing figure.
- Table 7-11: Compared tabulated values to GoldSim model with results. All are acceptable.
- Figure 7-30: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-31: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-32: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Table 4-12: Compared entries copied from source. Entries were equivalent.
- Figure 7-33: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-34: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Table 7-13: Compared tabulated values to GoldSim model with results. All are acceptable.
- Table 7-14: Compared tabulated values to GoldSim model with results. All are acceptable. Corrected table heading in report which said peak dose, reported value is a peak concentration.
- Figure 7-35: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-36: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-37: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-38: Visually compared graphic to GoldSim model with results. The two appear equivalent.

2/24/2020

Checker Log Addendum

- Figure 7-39: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-40: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Figure 7-41: Visually compared graphic to GoldSim model with results. The two appear equivalent.
- Table 7-16: Compared tabulated values to GoldSim model with results. All are acceptable.
- Figure 7-42: Visually compared graphic to GoldSim model with results. The two appear equivalent.

2/24/2020

EXECUTIVE SUMMARY

Cancer risks and non-cancer hazards to a receptor using groundwater at both the Waste Management Area (WMA) A-AX fenceline and 100 m from the closed WMA A-AX under the U.S. Environmental Protection Agency's residential tap water scenario were calculated using the WMA A-AX system model developed in GoldSim©[1].

No cancer risks were identified because no carcinogenic chemicals reach the point of calculation within the model's 10,000-year time frame.

The peak chemical non-cancer Hazard Index (HI) is about 0.035, peaking at 2,120 years post-closure, and is less than the target HI of one. This HI includes the contribution from all 241-A Tank Farm (A Farm) sources and occurs at the WMA A-AX fenceline. Early in the simulation (0 to 1,000 years post-closure), the HI is driven by chromium from A Farm non-tank sources. For the remainder of the simulation (1,000 to 10,000 years post-closure), HI is still driven by chromium from A Farm sources at its peak (in less than 2,000 years post-closure), but nitrite from tank sources, primarily tank 241-A-104, becomes the predominant contributor to HI through the rest of the simulation. Table ES-1 shows the results of the non-cancer hazard calculations for A Farm for all chemicals providing a non-zero hazard in the model's 10,000-year time frame at the fenceline, while Table ES-2 shows the same for the 100-m point of calculation. Table ES-3 shows the results of the non-cancer hazard calculations for 241-AX Tank Farm for all chemicals providing a non-zero hazard in the model's 10,000-year time frame at the fenceline, while Table ES-4 shows the same for the 100-m point of calculation.

Table ES-1. Summary of Peak Hazard Quotients from 241-A Tank Farm Sources at the 241-A Tank Farm Fenceline and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-Year Period		1,000- to 10,000-Year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	5.14E-07	1,000	4.15E-04	1,980
Fluoride	1.33E-10	1,000	6.75E-04	2,160
Nitrite	6.93E-09	1,000	3.23E-02	2,120
Nitrate	4.34E-10	1,000	1.95E-03	2,120
Uranium	0.00E+00	0	7.30E-09	10,000
Hazard Index	5.22E-07	1,000	3.53E-02	2,120

GoldSim© Elements:
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\A_NonRad_HQ_Peak_by_Analyte,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\A_NonRad_HQ_Peak_Time_by_Analy,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations\A_Total_HI

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[1] GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

Table ES-2. Summary of Peak Hazard Quotients from 241-A Tank Farm Sources at 100 meters Downgradient from Waste Management Area A-AX and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-Year Period		1,000- to 10,000-Year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	5.09E-07	1,000	4.15E-04	1,980
Fluoride	9.55E-11	1,000	4.82E-04	2,160
Nitrite	4.97E-09	1,000	2.31E-02	2,120
Nitrate	3.10E-10	1,000	1.39E-03	2,120
Uranium	0	0	7.22E-09	10,000
Hazard Index	5.14E-07	1,000	2.53E-02	2,120

GoldSim© Elements:
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\A_NonRad_HQ_Peak_by_Analyte,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\A_NonRad_HQ_Peak_Time_by_Analy,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations\A_Total_HI

Table ES-3. Summary of Peak Hazard Quotients from 241-AX Tank Farm Sources at the 241-AX Tank Farm Fenceline and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-Year Period		1,000- to 10,000-Year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	1.52E-07	1,000	1.08E-04	1,950
Fluoride	2.02E-12	1,000	6.14E-04	2,390
Nitrite	5.44E-11	1,000	1.39E-02	2,320
Nitrate	4.75E-12	1,000	1.36E-03	2,320
Uranium	0	0	5.38E-10	10,000
Hazard Index	1.52E-07	1,000	1.60E-02	2,320

GoldSim© Elements:
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_HQ_Peak_by_Analyte,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_HQ_Peak_Time_by_Ana,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations\AX_Total_HI

Table ES-4. Summary of Peak Hazard Quotients from 241-AX Tank Farm Sources at 100 meters Downgradient from Waste Management Area A-AX and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-Year Period		1,000- to 10,000-Year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	1.51E-07	1,000	1.08E-04	1,950
Fluoride	1.76E-12	1,000	2.63E-04	2,390
Nitrite	4.71E-11	1,000	5.97E-03	2,320
Nitrate	4.04E-12	1,000	5.81E-04	2,320
Uranium	0	0	5.35E-10	10,000
Hazard Index	1.51E-07	1,000	6.88E-03	2,310

GoldSim© Elements:
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_HQ_Peak_by_Analyte,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_HQ_Peak_Time_by_Ana,
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations\AX_Total_HI

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AMS	American Meteorological Society
BBI	Best-Basis Inventory
CCUz	Cold Creek Silt unit
CHPRC	CH2M HILL Plateau Remediation Company
COPC	constituent of potential concern
DCAL	Dose and Risk Calculation
DOE	U.S. Department of Energy
EMCF	Environmental Model Calculation File
EMMA	Environmental Model Management Archive
EPA	U.S. Environmental Protection Agency
HI	Hazard Index
HTWOS	Hanford Tank Waste Operations Simulator
HQ	Hazard Quotient
HSU	hydrostratigraphic unit
IMBA	Integrated Modules for Bioassay Assessment
MATLAB	matrix laboratory (software)
MCL	maximum contaminant level
MPR	model package report
PA	Performance Assessment
POC	point of calculation
PUREX	Plutonium Uranium Extraction (Plant)
RESRAD	RESidual RADioactive
SST	Single-Shell Tank
STOMP	Subsurface Transport Over Multiple Phases
TBP	Tributyl Phosphate
WMA	Waste Management Area
WRPS	Washington River Protection Solutions, LLC

1.0 PURPOSE

The purpose of this environmental model calculation file (EMCF) is to document the calculations performed for the analysis of hazardous chemical and dangerous waste constituent impacts from tank waste residuals left in Waste Management Area (WMA) A-AX tanks and ancillary equipment at closure.

1.1 OBJECTIVE

The objective of the modeling described in this EMCF is to calculate the risk and hazard impacts from the closed WMA A-AX over time. These impacts are cancer risk and non-cancer health effects to a receptor at both the WMA fenceline and 100 m downgradient from the closed WMA.

1.2 SUPPORTING DOCUMENTS

The calculations described in this EMCF use conceptual models and mathematical models that are appropriate for the intended use as documented in a series of data package reports, model package reports (MPRs), other environmental calculation reports, and/or other technical literature.

1.2.1 Data Package Reports

Data package reports are reports that are developed for use in the environmental model. Data package reports supporting this calculation support mathematical model selection, key assumptions and parameterization.

The data package reports that support this calculation are:

RPP-ENV-58813, Rev. 1	*Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*
RPP-RPT-58293, Rev. 2	*Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*
RPP-RPT-58693, preliminary draft	*Engineered System Data Package for Waste Management Area A-AX*

1.2.2 Model Package Reports

Model package reports describe the conceptual and mathematical models used in the calculation. The MPR supporting this calculation supports model implementation and is:

RPP-RPT-60885, in process	*Model Package Report System Model for the WMA A-AX Performance Assessment*

1.2.3 Other Environmental Model Calculation Files

The EMCFs supporting this calculation support parameterization and are:

RPP-CALC-62319, in process	*Residual Waste Source Inventory Term for the Waste Management Area A-AX Performance Assessment Inventory Case 1*
RPP-CALC-63247	*WMA A-AX Performance Assessment Sensitivity Analysis*

1.2.4 Other Technical Reports

RPP-ENV-58806, Rev. 1, in process	*RCRA Closure Analysis of Tank Waste Residuals Impacts at Waste Management Area C, Hanford Site, Washington*

1.3 DOCUMENT STRUCTURE

The structure of this EMCF follows the required structure of an EMCF.

- Section 2.0 provides supplemental background for the calculation.
- Section 3.0 describes calculation methodology.
- Section 4.0 describes the assumptions and inputs.
- Section 5.0 describes the computational software.
- Section 6.0 describes the output(s) from the environmental model.
- Section 7.0 provides the calculation results and conclusions.
- Section 8.0 is a list of references cited in this calculation report.

Attachment 1 contains the software installation and checkout forms for the GoldSim©[2] simulation software.

Attachment 2 contains the tank residual inventories used in the model for the risk and hazard impact calculations.

Attachment 3 contains the parameter inputs used for the tap water scenario calculated in this document.

Attachment 4 contains contaminant-specific inputs used for each exposure pathway of the tap water scenario calculated in this document.

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[2] GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

2.0 BACKGROUND

Details of the development of the system model used in the calculations described in this EMCF are provided in RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

2.1 HISTORY

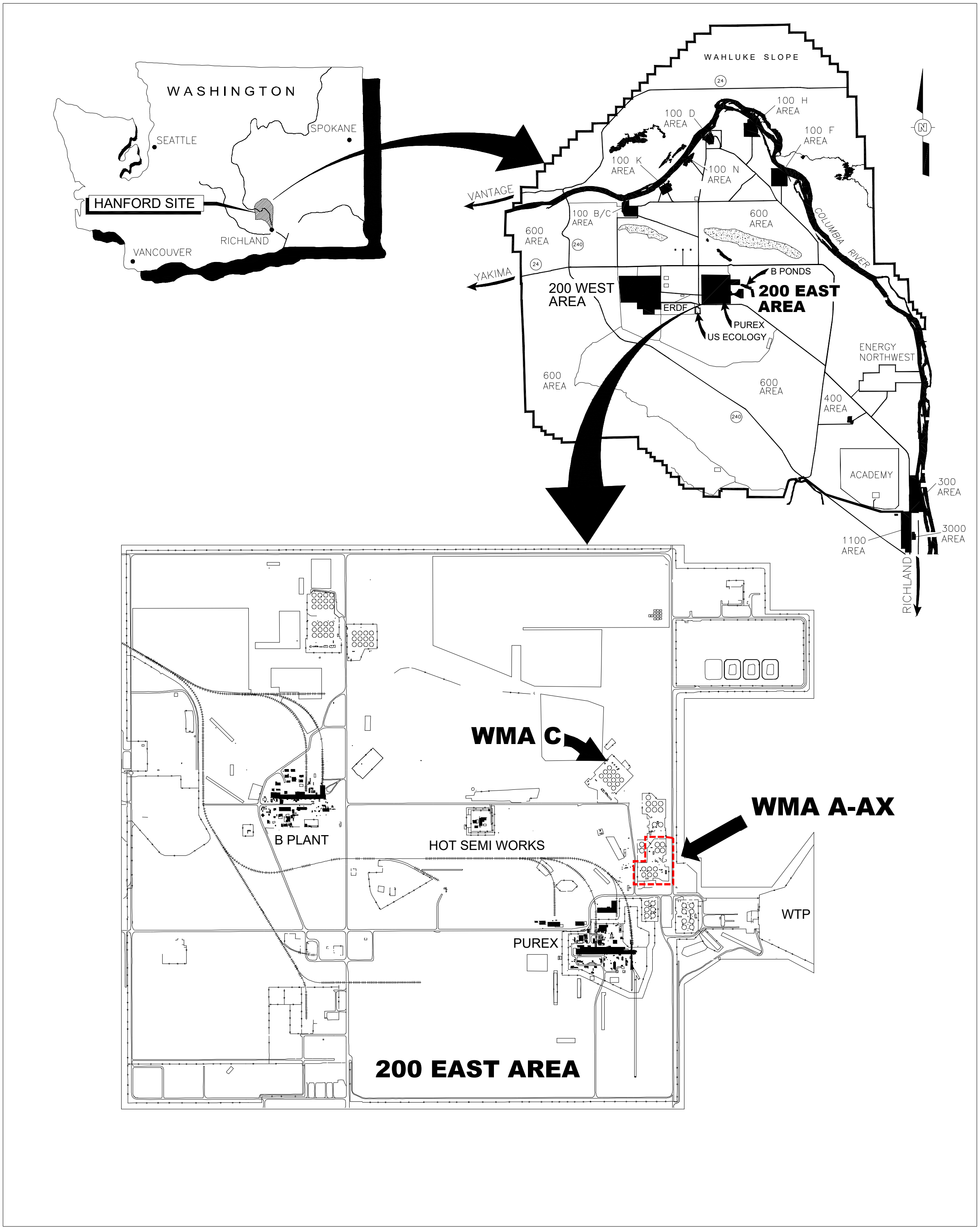
WMA A-AX comprises the 241-A and 241-AX Tank Farms and is located within the 200 East Area of the Central Plateau of the Hanford Site. The 241-A Tank Farm (A Farm) and 241-AX Tank Farm (AX Farm) were constructed between 1953 and 1955 and between 1963 and 1965, respectively. The WMA A-AX tank farms are surrounded by several other double-shell tank farms within the A Complex, and Single-Shell Tank (SST) Farm 241-C (C Farm) is located nearby to the northwest (Figure 2-1). WMA A-AX includes catch tanks, diversion boxes, valve pits, pipelines, French drains and unplanned release sites. Numerous liquid discharge facilities used at various times (cribs, trenches, ditches, septic systems, etc.) surround the WMA.

The tanks in both A Farm and AX Farm were designed for the storage of boiling waste generated from irradiated fuel reprocessing at the 202-A Plutonium Uranium Extraction (PUREX) Plant. A Farm contains six 75-ft diameter nominally 1,000,000-gal capacity SSTs that consist of a carbon steel liner inside a concrete tank. AX Farm contains four such SSTs of a later design. A Farm and AX Farm were placed in service in 1955 and 1965, respectively, and both were used to store and transfer waste until mid-1980.

Figure 2-2 illustrates the closure concept for WMA A-AX following tank waste retrieval. Surface facilities will be removed and retrieved SSTs 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 farm and will be monitored using existing wells.

In brief, as of 2018, plans for the future closure of A Farm and AX Farm call for retrieval of wastes remaining in the SSTs (mostly sludge and saltcake solids) to the maximum extent practicable, grouting the residual wastes and interior volume of the SSTs, and construction of a surficial barrier over the tank farms. The Performance Assessment (PA) uses numerical models to evaluate the potential risk and hazard impacts from hazardous chemical and dangerous waste constituent impacts from tank waste residuals left in the closed tanks and ancillary equipment of WMA A-AX.

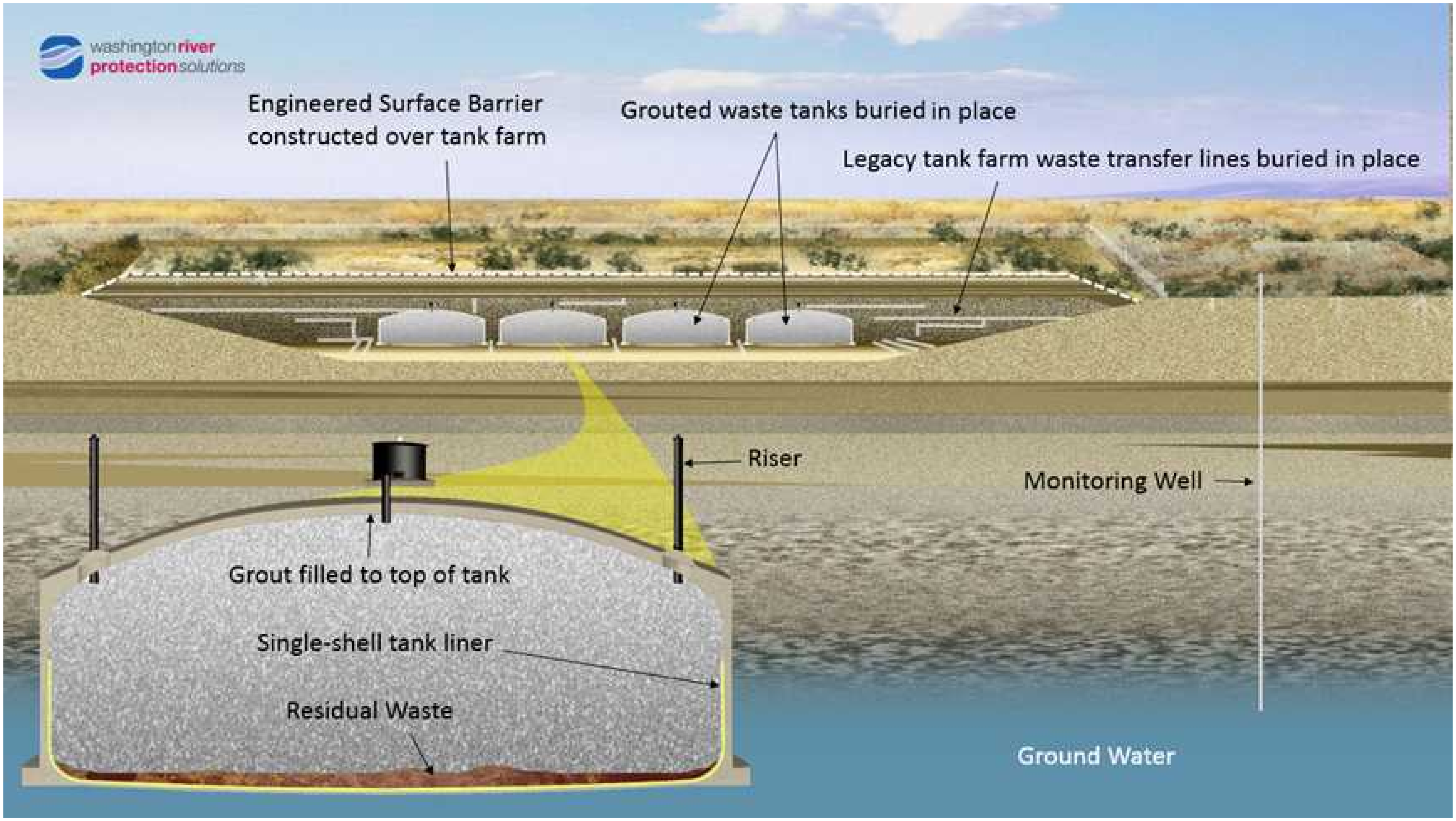
Figure 2-1. Location of Waste Management Area A-AX in Relation to Hanford Site.



H:\CHG\241-C TF\2E-WMA-C1A

PUREX = Plutonium Uranium Extraction (Plant) WMA = Waste Management Area WTP = Waste Treatment Plant

Figure 2-2. Conceptual Model of Closure of Waste Management Area A-AX.



2.2 JUSTIFICATION OF METHODOLOGY

The establishment of the groundwater pathway system model was described in RPP-RPT-60885. This work builds upon the model developed for the WMA A-AX PA, the justification for which has been established in the EMCFs written to support that effort.

The model includes releases from the tanks (six tanks in A Farm and four in AX Farm) and pipeline and ancillary equipment in the two farms. Distribution of the released constituents of potential concern (COPCs) in the vadose zone depends on the inventory, the liner system, transport of the contaminants through the vadose zone, and transport in the saturated zone to points of calculation (POCs) (WMA fenceline and 100 m downgradient from the facility boundary) for subsequent cancer risks and non-cancer hazards to humans from the potential use of the contaminated water at the POCs. The system model was developed by abstracting process modelling results and capturing key features, events, and processes related to barriers' safety functions, while maintaining computational efficiency.

The results obtained from the system model related to the groundwater pathway include the COPC concentration in the saturated zone at the WMA fenceline and the 100-m buffer boundary from which both cancer risks from chemicals and non-cancer hazards can be calculated using the U.S. Environmental Protection Agency (EPA)'s residential tap water scenario. Details of the development of the system model are provided in RPP-RPT-60885.

The system model for the WMA A-AX PA was developed by connecting the subsystem PA models of WMA A-AX using the GoldSim© computer code. GoldSim© is designed to simulate transport of COPCs accompanied with solubility-limit and sorption within modules allowing each waste source to be represented by a discrete element within the model.

3.0 METHODOLOGY

The system-level model is implemented using GoldSim© software (GoldSim Distributed Processing Module User's Guide, Version 12.0 [GoldSim Technology Group 2017]). The detailed methodology for various calculations performed with the system-level model is discussed in RPP-RPT-60885, except for chemical hazards calculation, which is detailed here.

3.1 SELECTION OF TECHNICAL STAFF

The responsible manager or a selected delegate is responsible for selecting the technical staff that develops the conceptual and mathematical approach, performs and documents the calculations, checks the work, and reviews the calculation for technical accuracy and completeness. For the calculations described in this EMCF, as delegated by the responsible manager:

- the Washington River Protection Solutions, LLC (WRPS) technical lead has selected the technical staff

- the INTERA, Inc. modeling team lead has selected additional technical staff.

3.1.1 Originators

The originators or preparers of the environmental model calculation develop the methodology; gain early concurrence with the senior reviewers; identify project conditions, assumptions, and inputs; and prepare the calculation and associated calculation report.

David J. (DJ) Watson (Washington River Protection Solutions), Scientist

MS, 2009, Environmental Science, Washington State University
BS, 1996, Geology, Washington State University

Mr. Watson has over 16 years of human health risk assessment and PA experience. He has over 13 years of environmental modeling experience, including: subsurface contaminant transport using STOMP©[3], pflotran[4], and TOUGH2[5]; air dispersion with AERMOD[6]; internal and external

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[3] Subsurface Transport Over Multiple Phases (STOMP)© is copyrighted by Battelle Memorial Institute, 1996.

[4] PFLOTRAN is open-source software and can be redistributed and/or modified under the terms of the GNU Lesser General Public License as published by the Free Software Foundation.

[5] TOUGH2 software was developed by Lawrence Berkeley National Laboratory, University of California, Berkeley, California with support from the Office of Science, Office of Basic Energy Sciences, Materials Sciences and Engineering Division of the U.S. Department of Energy.

[6] AERMOD atmospheric dispersion modeling system was developed by the AERMIC (American Meteorological Society [AMS]/EPA Regulatory Model Improvement Committee), a collaborative working group of scientists from the AMS and the EPA.

radiological dosimetry using IMBA®[7], DCAL[8], OLINDA[9], and RESRAD[10]; and system modeling using GoldSim©. He has worked in the areas of underground tank waste retrieval and tank closure, radiation dosimetry of both internally-deposited radionuclides and external exposure, nuclear fuel fabrication and transport, and geologic carbon dioxide (CO_2) sequestration. His work has supported the U.S. Department of Energy (DOE), U.S. Nuclear Regulatory Commission, International Atomic Energy Agency (IAEA), Joint Global Change Research Institute and other industrial and research organizations.

3.1.2 Checkers

The checker reviews the environmental model calculation to verify that it is clearly developed and that the calculation was performed as described and without error. Checking includes ensuring that all the inputs are consistent with the original referenced material. The checker documents the review of the calculation on an appropriate Checker Log.

Wei Zhou (INTERA, Inc.) Senior Engineer

PhD, 1992, Nuclear Engineering, University of California at Berkeley
MS, 1986, Mechanical Engineering, San Jose State University
BS, 1982, Mechanical Engineering, Beijing University of Technology

Dr. Zhou has more than 30 years of experience in the areas of performance and safety assessment of near-surface and deep geological radioactive waste repositories, risk assessments for organic wastes including dense and light non-aqueous phase liquids and volatile organic compounds, and the geological sequestration of CO_2. She has provided technical support in these areas to industrial, governmental, and international organizations such as the Electric Power Research Institute, IAEA, Nuclear Energy Institute, Korean Hydro and Nuclear Power, Canadian Petroleum Technology Research Institute, EPA, DOE, Swedish Nuclear Inspectorate, Japan Atomic Energy Agency, Taiwan Institute of Nuclear Energy Research, International Energy Agency, Nuclear Energy Agency, and the Commission for European Communities. She specializes in modeling and simulation of radionuclide transport, coupled heat and mass transfer in fractured media, as well as multiphase and multi-component transport systems using public or

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[7] Integrated Modules for Bioassay Assessment (IMBA)® is a registered trademark of Public Health England, London, United Kingdom; IMBA Expert™ DOE-Edition is a trademark of ACJ & Associates, Richland, Washington and U.K. Health Protection Agency, Oxfordshire, United Kingdom.

[8] DCAL (Dose and Risk Calculation) software was developed by the Dosimetry Research Group (now the Biosystems Modeling Team in the Advanced Biomedical Science and Technology Group) at Oak Ridge National Laboratory under the sponsorship of the U.S. Environmental Protection Agency.

[9] OLINDA code was written by Michael Stabin, PhD, CHP, Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, Tennessee.

[10] The RESRAD (RESidual RADioactive) family of codes is developed at Argonne National Laboratory, Lemont, Illinois, managed by UChicago Argonne, LLC, for the U.S. Department of Energy's Office of Science.

commercial codes including TOUGH2, TOUGHREACT[11], STOMP©, ECLIPSE suite codes[12], MATLAB®[13], and GoldSim©. Her expertise also includes developing customized software using FORTRAN and C++. She has completed all reading assignments that are procedurally required to perform environmental fate and transport calculations.

Dr. Zhou was the lead checker for this work and reviewed the GoldSim© model, verifying that inputs in the model matched the source documents, the model was implemented correctly for the intended purpose, and the outputs were exported correctly.

3.1.3 Senior Reviewers

Matthew W. Kozak (INTERA, Inc.)

PhD, 1988, Chemical Engineering, University of Washington
BS, 1981, Chemical Engineering, Cleveland State University

Dr. Kozak has more than 30 years of experience in the areas of performance assessment of near-surface and geological radioactive waste repositories, regulatory development, dose assessment for residual contamination of soils and buildings, toxic materials risk assessment, and mixed waste issues. He is the author of over 100 publications on these topics. He has supported national programs in the U.S. and countries in Europe, Asia, and Africa to site, develop, construct, and analyze facilities for disposal of radioactive waste.

Dr. Kozak has participated in a number of international research programs, including the IAEA's Coordinated Research Program on Improvement of Safety Assessment Methodologies, and its successor programs: Application of Safety Assessment Methodologies, Practical Illustration and Use of the Safety Case Concept in the Management of Near-Surface Disposal, and most recently Modelling and Data for Radiological Impact Assessments.

He is a principal investigator for the WMA A-AX PA.

3.2 CONCEPTUAL MODEL

The conceptual model of the source term, release mechanisms, vadose zone transport and saturated zone transport are fully described in RPP-RPT-60885. To fulfill requirements set forth in the HFFACO Action Plan, Appendix I, this calculation analyzes impacts from hazardous chemical and dangerous waste constituents in tanks and ancillary equipment, which are anticipated to remain in WMA A-AX after closure.

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[11] TOUGHREACT software was developed by Lawrence Berkeley National Laboratory, University of California, Berkeley, California with support from the Office of Science, Office of Geothermal Technologies of the U.S. Department of Energy.

[12] ECLIPSE is a suite of reservoir simulator software developed by GeoQuest, an operating unit of Schlumberger Oilfield Services, Houston, Texas.

[13] MATLAB® (matrix laboratory) is a registered trademark of The MathWorks, Inc., Natick, Massachusetts.

To meet requirements of *Resource Conservation and Recovery Act of 1976* (RCRA), risk-based calculations are performed using the tap water (resident) scenario. This scenario is used to estimate exposure to hazardous chemical and dangerous waste constituents to a resident receptor who uses the contaminated water from the well located at the POC for domestic purposes. This assumes that a well is drilled 100 m downgradient of the WMA and water from this well is used for domestic purposes. The exposure assumptions in this scenario reflect reasonable maximum exposure. Exposure parameters and toxicity values that are used in the equations are obtained from EPA guidance.

The receptor is assumed to be exposed to hazardous chemical and dangerous waste constituents in groundwater from the following exposure routes:

- Ingestion of tap water

- Inhalation of volatile chemicals while showering and other domestic purposes

- Dermal contact with skin while showering and using groundwater for other domestic purposes (such as washing dishes).

Excess lifetime cancer risks for carcinogens and non-cancer hazards for noncarcinogens are calculated. Estimation of intake is based on age-specific ingestion, inhalation and dermal contact rates for children and adults assuming 6-year exposure duration for children and 20-year exposure duration for the adults. Figure 3-1 provides the conceptual exposure model for the tap water (residential scenario) and shows all of the elements of a complete exposure pathway.

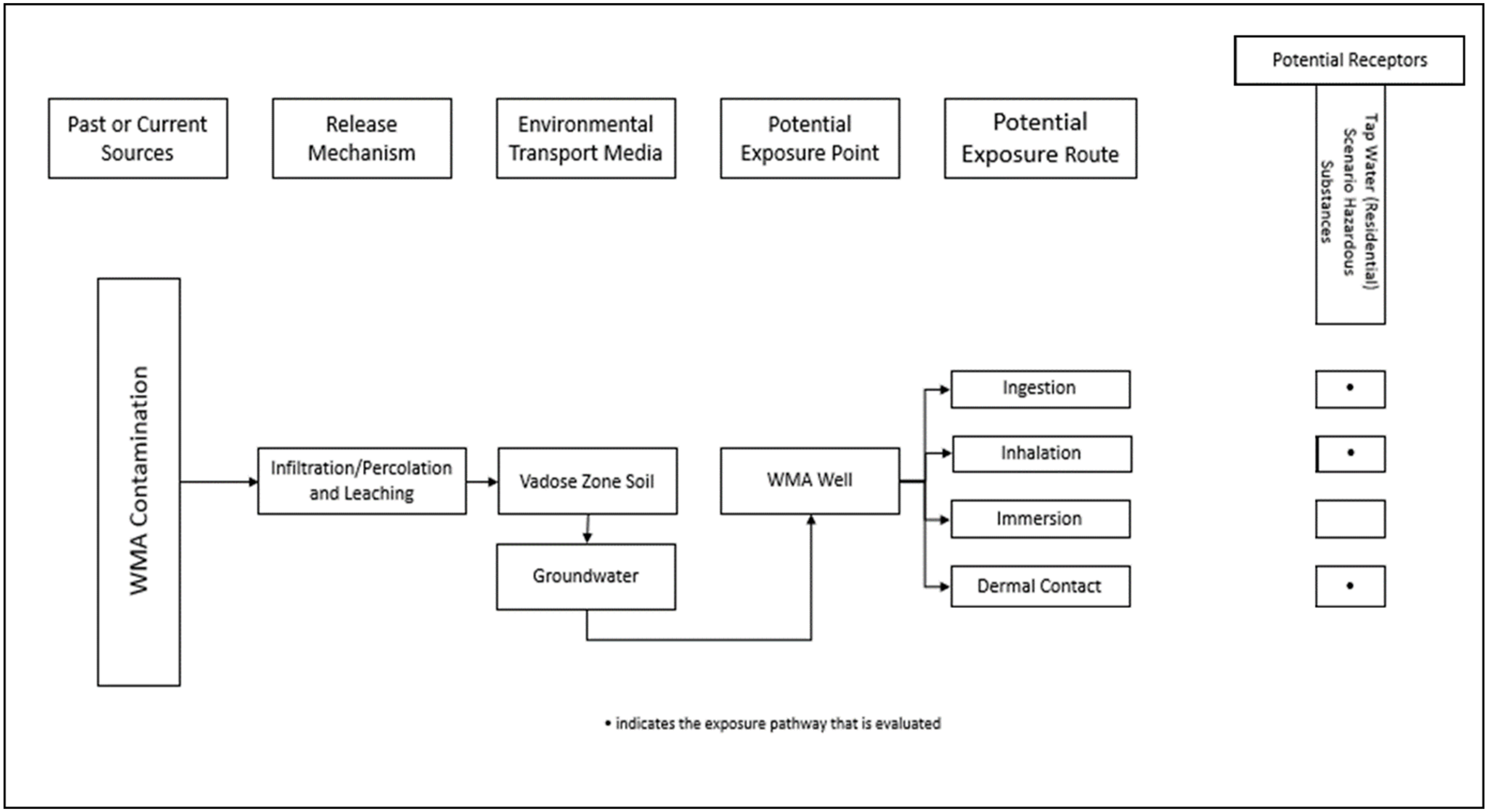
Risk-based concentrations are based on equations and exposure assumptions presented in RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington* using a target risk level of 1×10^{-6} and a cumulative risk level of 1×10^{-5} for carcinogens or a Hazard Quotient (HQ) of 1 and Hazard Index (HI) of 1 for noncarcinogens.

Sensitivity analyses including both radionuclides and chemicals were performed for RPP-ENV-61497, *Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington*. The conceptual model for these analyses are fully described in RPP-CALC-63247 and are listed in Table 3-1.

3.3 MATHEMATICAL MODEL

The following section provides the mathematical model used to calculate cancer and non-cancer risks from exposure to hazardous chemicals from the closed WMA A-AX. Each exposure pathway used in the EPA tap water scenario is detailed in the following sections. A summary of the exposure assumptions used for each of the exposure pathways is provided in Attachment 3 while Attachment 4 lists the chemical-specific parameters used for cancer risks and non-cancer hazards.

Figure 3-1. Conceptual Exposure Model for the Tap Water (Residential) Scenario.



WMA = Waste Management Area

Table 3-1. Sensitivity Analysis Cases for the Waste Management Area A-AX Impacts Analysis. (2 sheets)

Sensitivity Case	Description
Surface Barrier Sensitivity Cases	
INF0	Base case, 0-500 years 0.5 mm/yr, after 500 years 3.5 mm/yr.
INF1	This is a case in which the surface barrier continues to provide limitation to flow beyond its design life. Recharge rate 0.5 mm/yr in entire 10,000-year time period reflecting intact surface barrier condition.
INF2	This is a case which assumes the absence of a surface barrier, and gravel surface on the tank farm. Recharge rate 100 mm/yr in entire 10,000-year time period reflecting recharge rate for Hanford operation period for gravel-dominated surface cover.
INF3	This is a case which assumes the absence of a surface barrier, and natural vegetation on the tank farms. Recharge rate 3.5 mm/yr in entire 10,000-year time period reflecting recharge rate for natural vegetation-covered surface.
Inventory Sensitivity Cases	
INV0	Base case, based on projected inventory after retrieval except tanks 241-A-104 and 241-A-105 which are assumed not to be retrieved.
INV1	Based on current inventory. This is an exploration of alternative inventory assuming no retrieval for the tanks.
INV2	All parameters same as base case, except that the estimated inventory for ancillary equipment is based on average Best-Basis Inventory concentration of the tanks. This is an exploration of alternative inventory for the ancillary equipment.
Grout Sensitivity Cases	
GRT0	Base case, grout intact for evaluation period (10,000 years).
GRT1	All parameters same as base case, except that after 500 years following closure, the grout degrades and the flow properties change to Hanford formation unit 2 (H2) sand values, with a step function change in the flow rate occurring at this time. This is a loss of the flow safety function of the grout. This represents an alternative in which the grout degradation is more rapid than the base case through degradation processes such as unanticipated seismic activity.
GRT2	All parameters same as base case, except that beginning from closure (time zero), the grout is assumed to be degraded and the flow properties are represented by Hanford H2 sand values. This represents a complete loss of the flow safety function at the time of closure.
GRT3	K_d values on grout are set equal to zero for all chemicals. This case evaluates the effect from loss of the chemical safety function of the grout material. There is no known feature, event, or process to produce this condition. It has been included to evaluate the robustness of the system.
Tank Shell Sensitivity Cases	
TS0	Base case, tank shell provides no containment.

Table 3-1. Sensitivity Analysis Cases for the Waste Management Area A-AX Impacts Analysis. (2 sheets)

Sensitivity Case	Description
TS1	Tank shell prevents release from waste zone for 5,000 years, then diffusive release to the vadose zone. The function of the carbon steel shell to limit release through the tank is not currently explicitly accounted for in the base case and this case evaluates the effect of containing the waste by carbon steel shell, possibly allowing ingrowth of decay chain progeny.
Base Mat Sensitivity Cases	
BM0	Base case, assumes diffusion through base mat for 10,000 years for all tanks.
BM1	Assumes advection through base mat at all times for all tanks (Note: intact grout over failed base mat). This case is designed to study the effect of a degraded base mat on transport of residual waste constituents. It represents a loss of the flow safety function of the base mat.

Source: RPP-CALC-63247, *WMA A-AX Performance Assessment Sensitivity Analysis*, Table 2-2.

3.3.1 Equations Used to Calculate Cancer Risks and Non-Cancer Hazard Quotients from Exposure to Hazardous Substances

The following sections provide the equations used to calculate cancer risks and non-cancer hazards from exposure to hazardous chemicals through ingestion of water, dermal contact with water and inhalation of volatiles.

3.3.1.1 Ingestion of Hazardous Substances in Tap Water. This work uses the following equations (RPP-ENV-58813) to calculate cancer risks from ingestion of tap water.

$$Risk = \frac{C_w \times EF_r \times IFW_{r-adj} \times UCF_1 \times CSF_o}{AT_c} \tag{3-1}$$

Where:
C_w = groundwater concentration (µg/L)
EF_r = exposure frequency—resident (days/year)
$IFW_{r\text{-}adj}$ = water ingestion rate—age-adjusted resident (L-yr/kg-day) (Equation 3-2)
UCF_1 = unit conversion factor (mg/µg) (note: GoldSim© automatically converts units, so this term is not used in the model)
CSF_o = slope factor—oral $(\text{mg/kg-day})^{-1}$
AT_c = carcinogenic averaging time —resident (days).

$$IFW_{r-adj} = \frac{ED_{r-c} \times IRW_{r-c}}{BW_c} + \frac{ED_{r-a} \times IRW_{r-a}}{BW_a} \tag{3-2}$$

Where:
$IFW_{r\text{-}adj}$ = water ingestion rate—age-adjusted resident (L-yr/kg-day)
$ED_{r\text{-}c}$ = exposure duration—child resident (years)
$IRW_{r\text{-}c}$ = water ingestion rate—child resident (L/day)

BW_c = body weight—child (kg)
$ED_{r\text{-}a}$ = exposure duration—adult resident (years)
$IRW_{r\text{-}a}$ = water ingestion rate—adult resident (L/day)
BW_a = body weight—adult (kg).

This work uses the following equation (RPP-ENV-58813) to calculate the non-cancer HQ from ingestion of tap water.

$$HQ = \frac{C_w \times EF_r \times IRW_{r-c} \times UCF_1 \times ED_{r-c}}{BW_c \times AT_{nc} \times RfD_o} \tag{3-3}$$

Where:

C_w = groundwater concentration (µg/L)
EF_r = exposure frequency—resident (days/year)
$IRW_{r\text{-}c}$ = water ingestion rate—child resident (L/day)
UCF_1 = unit conversion factor (mg/µg) (note: GoldSim© automatically converts units, so this term is not used in the model)
$ED_{r\text{-}c}$ = exposure duration—child resident (years)
BW_c = body weight—child (kg)
AT_{nc} = noncarcinogenic averaging time —resident (days)
RfD_o = chronic oral reference dose (mg/kg-day).

3.3.1.2 Dermal Contact with Hazardous Substances in Tap Water. This work uses the following equations (RPP-ENV-58813) to calculate cancer risk from dermal contact with tap water.

$$Risk = \frac{DA_{event} \times EF_r \times EV_r \times SA_{r-adj} \times \frac{CSF_0}{GIABS}}{AT_c} \tag{3-4}$$

Where:

DA_{event} = absorbed dose per event (mg/cm^2-event)
EF_r = exposure frequency—resident (days/year)
EV_r = event frequency—resident (events/day)
$SA_{r\text{-}adj}$ = skin surface area—age-adjusted resident (cm^2-yr-event/kg-day) (Equation 3-5)
CSF_o = slope factor—oral (mg/kg-day)$^{-1}$
$GIABS$ = fraction of contaminant absorbed in gastrointestinal tract (unitless)
AT_c = carcinogenic averaging time—resident (days).

$$SA_{r-adj} = \frac{ED_{r-c} \times SA_{r-c}}{BW_c} + \frac{ED_{r-a} \times SA_{r-a}}{BW_a} \tag{3-5}$$

Where:

$ED_{r\text{-}c}$ = exposure duration—child resident (years)
$SA_{r\text{-}c}$ = skin surface area—child resident (cm^2)
BW_c = body weight—child (kg)
$ED_{r\text{-}a}$ = exposure duration—adult resident (years)
$SA_{r\text{-}a}$ = skin surface area—adult resident (cm^2)
BW_a = body weight—adult (kg).

This work calculates the non-cancer HQs from dermal contact with tap water using the following equation (RPP-ENV-58813).

$$HQ = \frac{DA_{event} \times EF_r \times EV_r \times SA_{r-c} \times ED_{r-c}}{AT_{nc} \times BW_c \times RfD_o \times GIABS} \tag{3-6}$$

Where:

DA_{event} = absorbed dose per event (mg/cm^2-event)
EF_r = exposure frequency—resident (days/year)
EV_r = event frequency—resident (events/day)
$SA_{r\text{-}c}$ = skin surface area—child resident (cm^2)
$ED_{r\text{-}c}$ = exposure duration—child resident (years)
AT_{nc} = noncarcinogenic averaging time—resident (days)
BW_c = body weight—child (kg)
RfD_o = chronic oral reference dose (mg/kg-day)
$GIABS$ = fraction of contaminant absorbed in gastrointestinal tract (unitless).

3.3.1.2.1 Dermal Absorbed Dose. While there are equations for calculating the dermally-absorbed dose per event (DA_{event}) from organics (RPP-ENV-58813), the model does not implement them because Tributyl Phosphate (TBP) is the only organic chemical in the Best-Basis Inventory (BBI) and the inventory of TBP in all WMA A-AX tanks is zero.

For inorganic chemicals, this work uses the following steady-state equation to estimate DA_{event}:

$$DA_{event} = K_p \times C_w \times T_{event} \times UCF_1 \times UCF_2 \tag{3-7}$$

Where:

DA_{event} = absorbed dose per event (mg/cm^2-event)
K_p = dermal permeability coefficient (cm/hour)
C_w = groundwater concentration (µg/L)
T_{event} = event duration (hours/event) (Equation 3-8 [non-carcinogens] or 3-9 [carcinogens])
UCF_1 = unit conversion factor (mg/µg) (note: GoldSim© automatically converts units, so this term is not used in the model)

UCF_2 = unit conversion factor (L/cm^3) (note: GoldSim© automatically converts units, so this term is not used in the model).

For non-carcinogens, the event duration is calculated by:

$$T_{event} = T_{event-r-c} \tag{3-8}$$

For carcinogens, the event duration is calculated by:

$$T_{event} = T_{event-r-adj} = \frac{T_{event-r-c} \times ED_{r-c} + T_{event-r-a} \times ED_{r-a}}{ED_r} \tag{3-9}$$

Where:

$T_{event\text{-}r\text{-}adj}$ = event duration—age-adjusted resident (hours/event)
$T_{event\text{-}r\text{-}c}$ = event duration—child resident (hours/event)
$ED_{r\text{-}c}$ = exposure duration—child resident (years)
$T_{event\text{-}r\text{-}a}$ = event duration—adult resident (hours/event)
$ED_{r\text{-}a}$ = exposure duration—adult resident (years)
ED_r = exposure duration—resident (years).

3.3.1.3 Inhalation of Volatile Hazardous Substances in Tap Water. This work calculates the cancer risks and non-cancer HQs for the inhalation pathway using the following equations (RPP-ENV-58813).

$$Risk = \frac{C_w \times EF_r \times ED_r \times ET_r \times UCF_3 \times K \times IUR}{AT_c} \tag{3-10}$$

And:

$$HQ = \frac{C_w \times UCF_1 \times EF_r \times ED_{r-c} \times ET_r \times UCF_3 \times K}{AT_{nc} \times RfC} \tag{3-11}$$

Where:

C_w = water concentration (µg/L)
EF_r = exposure frequency—resident (days/year)
ED_r = exposure duration—resident (years)
ET_r = exposure time—resident (hours/day)
UCF_3 = unit conversion factor (day/hour) (note: GoldSim© automatically converts units, so this term is not used in the model)
K = Andelman volatilization factor (L/m^3)
IUR = inhalation unit risk (µg/m^3)$^{-1}$
AT_c = carcinogenic averaging time (days)
UCF_1 = unit conversion factor (mg/µg) (note: GoldSim© automatically converts units, so this term is not used in the model)

$ED_{r\text{-}c}$ = exposure duration—resident child (years)
$ED_{r\text{-}a}$ = exposure duration—resident adult (years)
AT_{nc} = noncarcinogenic averaging time (days)
RfC = chronic inhalation reference concentration (mg/m^3).

3.3.2 Equations to Calculate Cumulative Cancer Risk and Non-Cancer Hazard Index

The following sections provide the equations used to calculate cumulative cancer risk and non-cancer HI.

3.3.2.1 Cumulative Cancer Risk. This work estimates the cancer risk from exposure to a chemical from all routes of exposure using the following equation (RPP-ENV-58813):

$$Risk_T = \sum_1^N Risk_i \tag{3-12}$$

Where:

$Risk_T$ = total cancer risk from chemical (unitless)
$Risk_i$ = cancer risk for the i^{th} route of exposure (unitless)
N = number of routes of exposure.

This work estimates the cancer risks from exposure to multiple carcinogens from a single exposure route using the following equation, based on RPP-ENV-58813:

$$Risk = \sum_1^N Risk_{T,j} \tag{3-13}$$

Where:

$Risk$ = cumulative cancer risk (unitless)
$Risk_{T,j}$ = total cancer risk for the j^{th} chemical (unitless)
N = number of chemicals.

3.3.2.2 Non-Cancer Hazard Index. This work estimates the HQ for exposure to a hazardous chemical from all routes of exposure using the following equation based on RPP-ENV-58813:

$$HQ_T = \sum_1^N HQ_i \tag{3-14}$$

Where:

HQ_T = hazard quotient for chemical (unitless)
HQ_i = hazard quotient for the i^{th} route of exposure (unitless)
N = number of routes of exposure.

This work estimates the HI from exposure to multiple hazardous chemicals using the following equation based on RPP-ENV-58813:

$$HI = \sum_1^N HQ_{T,j} \tag{3-15}$$

Where:

HI = hazard index (unitless)
$HQ_{T,j}$ = hazard quotient of the j^{th} chemical (mg/kg-day) (Equation 3-14)
N = number of chemicals.

3.4 CALCULATION PROCEDURE

The WMA A-AX residential tap water scenario submodel is part of the WMA A-AX system model, which was constructed in GoldSim© Version 12.0 (RPP-RPT-60885). This section describes how the WMA A-AX residential tap water scenario submodel was constructed, including how data from RPP-CALC-62319, *Residual Waste Source Inventory Term for the Waste Management Area A-AX Performance Assessment Inventory Case 1*, RPP-ENV-58813 and RPP-ENV-58806, *RCRA Closure Analysis of Tank Waste Residuals Impacts at Waste Management Area C, Hanford Site, Washington* were incorporated into the calculations.

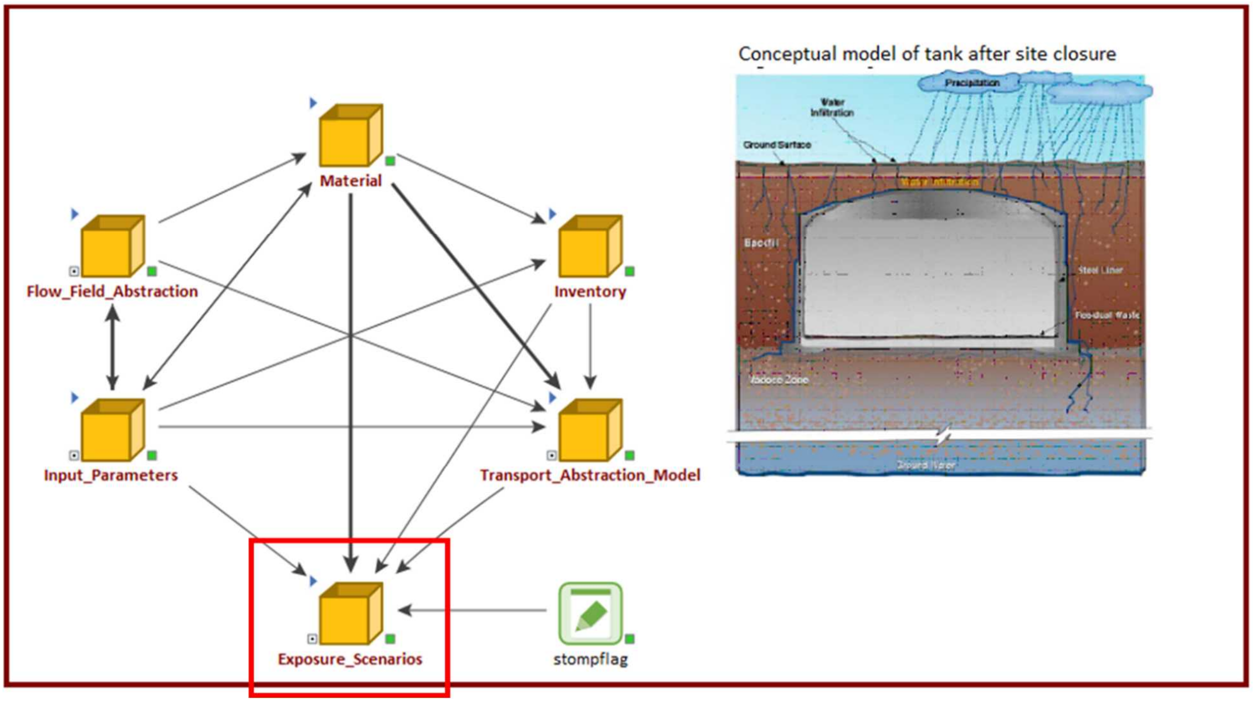
The residential tap water scenario calculations and parameters are all contained within the **Residential_Tap_Water_Scenario** element, which itself is contained within the **Exposure_Scenarios** container of the WMA A-AX system model. Figure 3-2 shows the root level of the WMA A-AX system model and highlights the containers used in the residential tap water scenario calculations.

The list of hazardous chemical COPCs is developed from RPP-CALC-62319. Radionuclides are not included in the residential tap water scenario calculations. Since the hexavalent form of chromium represents a potentially substantial contributor to cancer risk and non-cancer hazards, it was added to the **Chemicals** array labels. To facilitate applying the chromium inventory to either the hexavalent chromium or total chromium (simply called "chromium" in the model) array label, a data element called **Cr6_Switch** was created (GoldSim© element: **\Transport_Abstraction_Model\SZ_100m_Conc\Cr6_Switch**). When true, all the chromium inventory is applied to the chromium array label; otherwise all of the chromium inventory is applied to total chromium. This is accomplished in the **Chem_Conc_100m_Data** (GoldSim© element: **\Transport_Abstraction_Model\SZ_100m_Conc\Chem_Conc_100m_Data**) where two if/then statements were added:

- For chromium: If **Cr6_Switch** = False, then use the tank's transport model chromium concentration, otherwise use 0 g/L

- For hexavalent chromium: If **Cr6_Switch** = True, then use the tank's transport model chromium concentration, otherwise use 0 g/L.

Figure 3-2. Root Level of the Waste Management Area A-AX System Model.



Note: Residential tap water scenario calculations are performed in the Exposure_Scenarios container outlined in red. Groundwater transport calculations prior to residential tap water scenario calculations are performed using elements from the remaining containers, which are described in RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

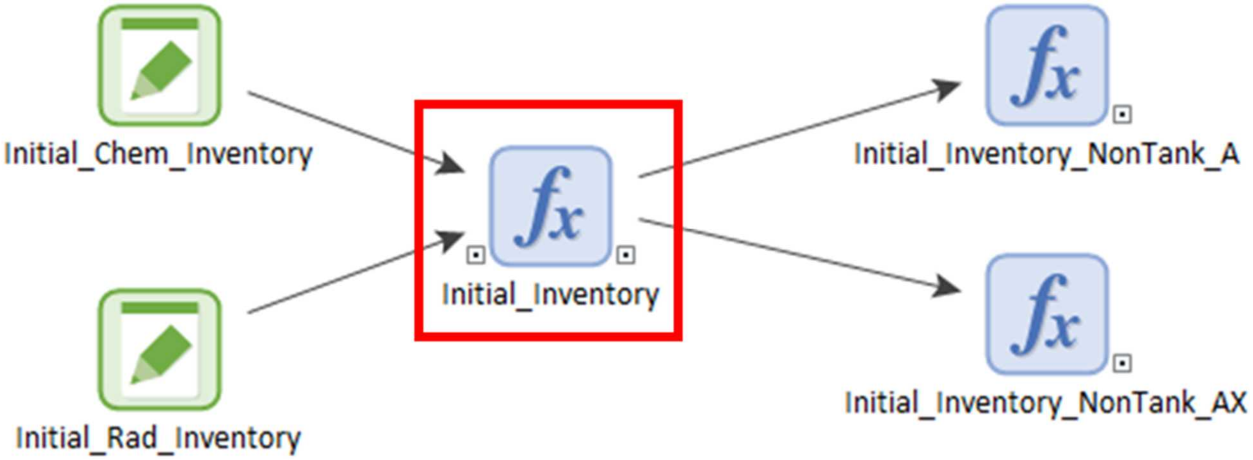
For these calculations, chromium is assumed to be all chromium, so **Cr6_Switch** is set to "False".

The initial inventories at the closure date of 2050 are contained in the **Inventory** module (Figure 3-3) and are listed in Attachment 2. Associated waste volumes used in waste form release calculations are contained in the **Eng_Sys_Transport_Param** container in the **Input_Parameters** container (Figure 3-2) and are listed in Attachment 2. The source term conceptual model and its implementation in the system model are detailed in RPP-RPT-60885.

Groundwater transport calculations are performed using the **Transport_Abstraction_Model** and **Flow_Field_Abstraction** containers, using tank and subsurface parameters defined in the **Material** container (Figure 3-2). The conceptual model for, and implementation of, groundwater transport are fully described in RPP-RPT-60885.

The containers within the **Residential_Tap_Water_Scenario** module (contained within the **Exposure_Scenario** module shown in Figure 3-2) are shown in Figure 3-4. **Species_specific_parameters** (Figure 3-5) contains all of the parameters in the residential tap water scenario that are contaminant-specific (Attachment 4), while the **Scenario_specific_parameters** contain all of the parameters specific to the residential tap water scenario (Figure 3-6, Attachment 3). **Risk_Calculations** (Figure 3-7) contains all of the residential tap water scenario cancer risk and HQ/HI calculations. **Fenceline_Switch** is a data element used in the GoldSim© Scenario Manager for selecting the WMA fenceline or 100-m downgradient groundwater concentrations for risk or hazard calculations. **GW_Concentrations** is an expression element that copies the appropriate groundwater concentration data to **GW_Concentration_Data** based on the value contained in **Fenceline_Switch**. **GW_Concentration_Data** is used in the calculations within the **Risk_Calculations** and **Risk_Calculation_Results** containers. Using the GoldSim© Scenario Manager facilitates direct comparison of results from multiple datasets.

Figure 3-3. Inventory Container of the Waste Management Area A-AX System Model.



Note: Elements used in the residential tap water calculations are indicated with red outline boxes.

3.4.1 Input Definitions

3.4.1.1 Material Container. The **Material** container is described in RPP-RPT-60885, Section 4.5.3.1.1.

3.4.1.2 Inventory Container. The **Inventory** container is described in RPP-RPT-60885, Section 4.5.3.1.2.

3.4.1.3 Transport_Abstraction_Model Container. The **Transport_Abstraction_Model** container is described in RPP-RPT-60885, Section 4.3.

3.4.1.4 Scenario_specific_parameters Container. Scenario_specific_parameters (Figure 3-6) contains scalar data elements of, and expressions calculating parameters specific to, the residential tap water scenario found in Tables H-1 and H-2 of RPP-ENV-58813. The elements, their corresponding parameters, the values used and their sources are detailed in Attachment 3.

The **Scenario_specific_parameters** container has three calculated parameters, as follows.

- **t_event_adjr**: This calculates the age-adjusted event duration for carcinogens ($T_{event\text{-}r\text{-}adj}$) using Equation 3-9.

- **IFW_radj_nonrad**: This calculates the age-adjusted water ingestion rate for chemicals ($IFW_{r\text{-}adj}$) using Equation 3-2.

- **SA_radj**: This calculates the age-adjusted skin surface area ($SA_{r\text{-}adj}$) using Equation 3-5.

Figure 3-4. Residential_Tap_Water_Scenario Container of the Waste Management Area A-AX System Model.

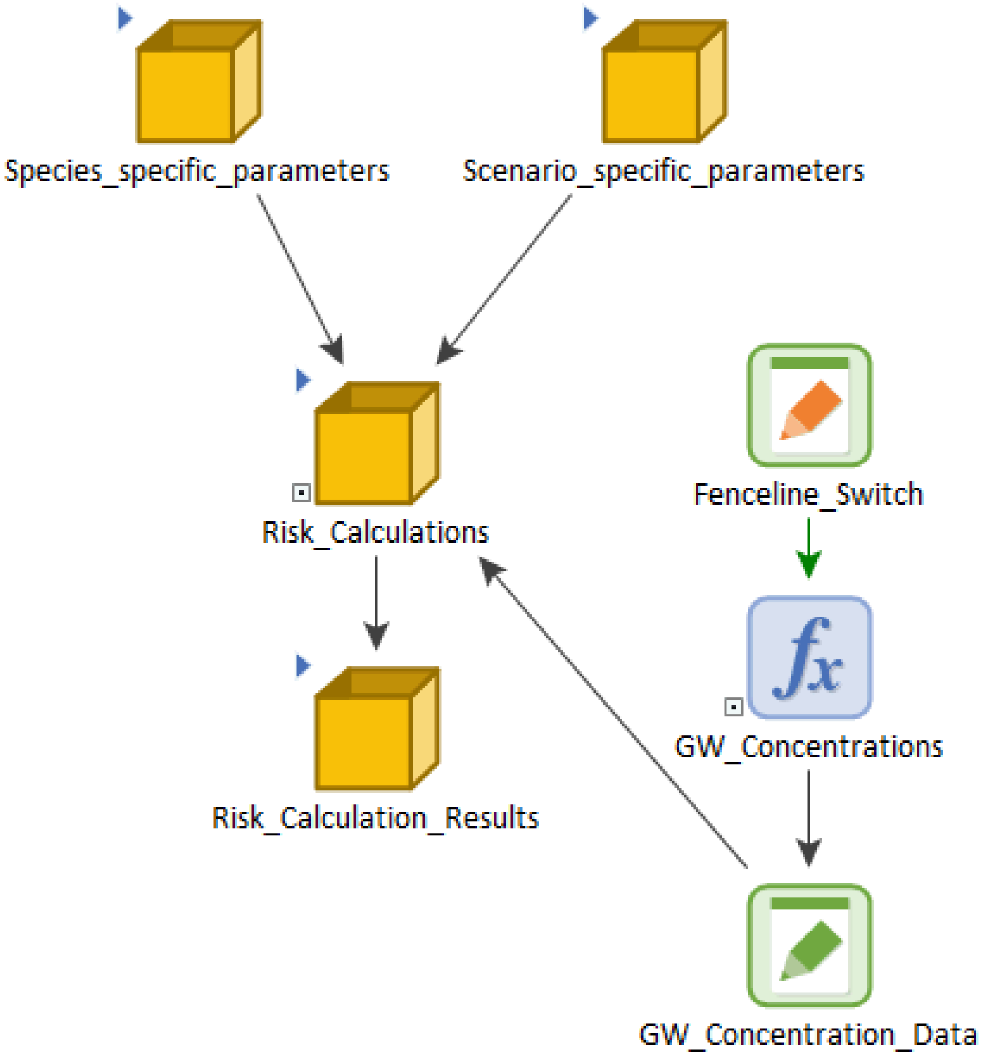
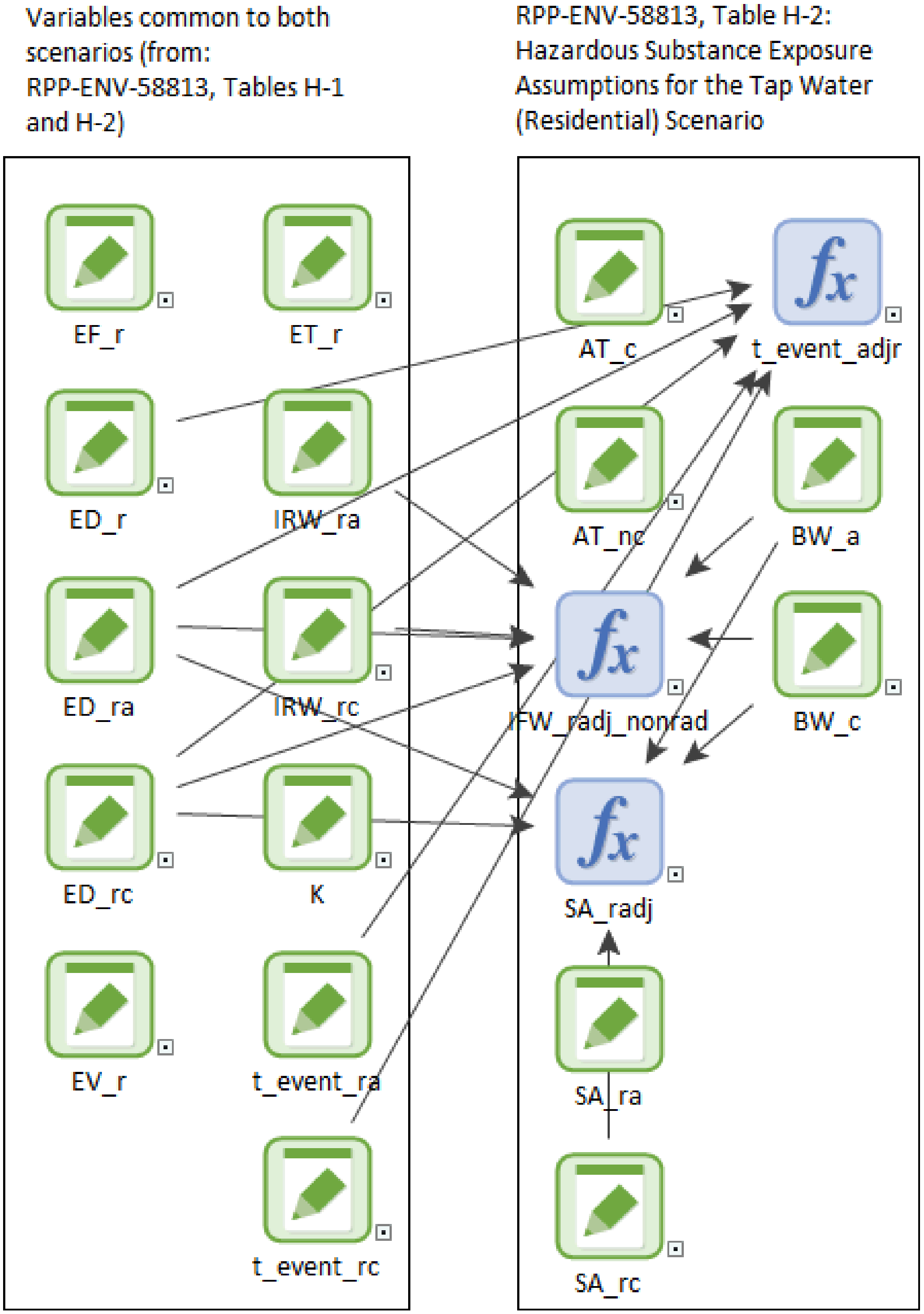


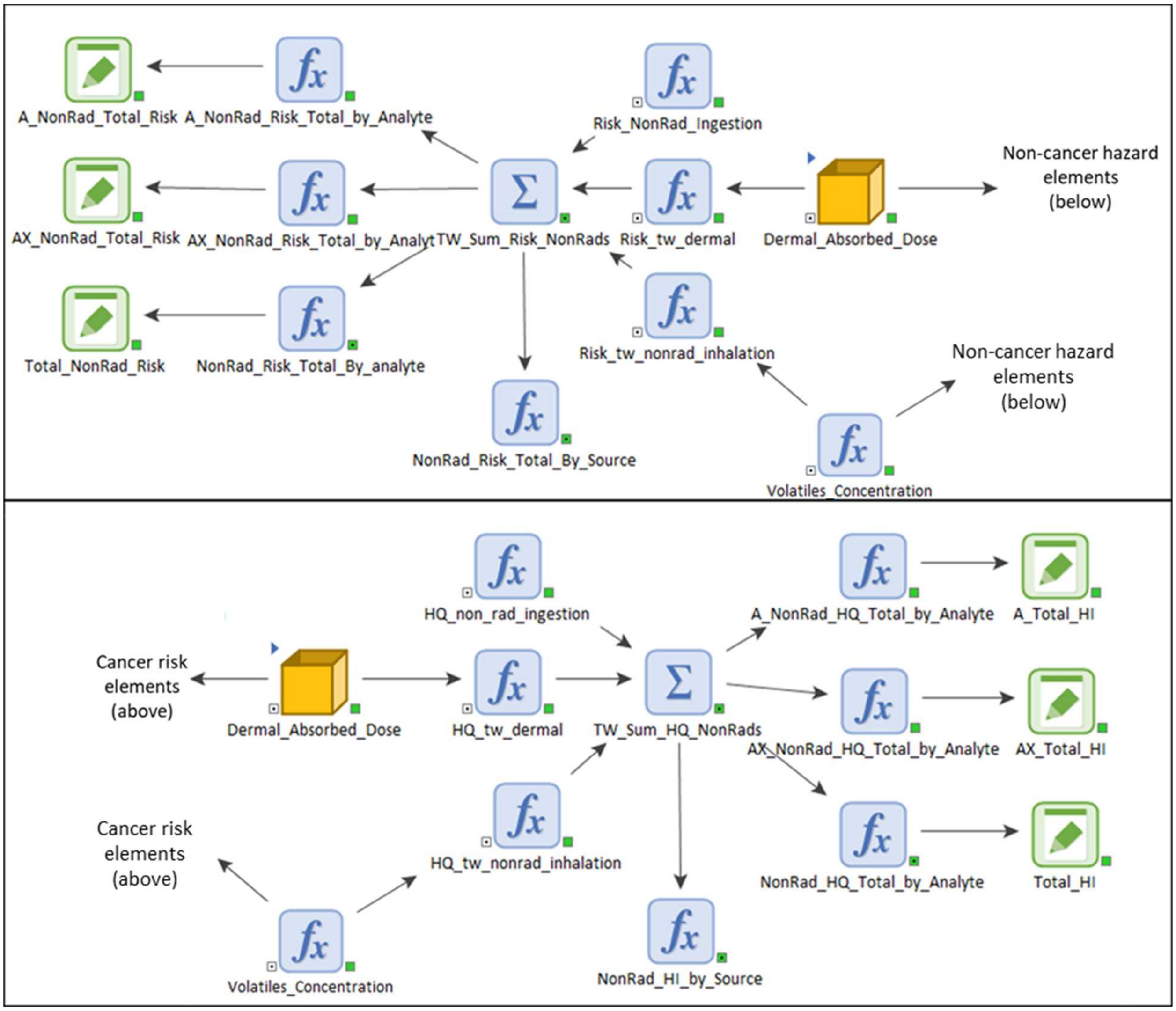
Figure 3-5. Species_specific_parameters Container of the Waste Management Area A-AX System Model.

Figure 3-6. Scenario_specific_parameters Container of the Waste Management Area A-AX System Model.



Reference: RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site*.

Figure 3-7. Risk_Calculations Container of the Waste Management Area A-AX System Model.



3.4.1.5 Species_specific_parameters Container. Species_specific_parameters (Figure 3-5) holds vector data elements of type "Chemicals" containing contaminant-specific parameters used in the residential tap water scenario calculations described in RPP-ENV-58813 and found in Tables 7-19 and 7-20 of RPP-ENV-58806 and Table H-2 of RPP-ENV-58813. The elements, their corresponding parameters, the values used and their sources are detailed in Attachment 4.

3.4.1.6 Sensitivity Elements. Sensitivity analysis-related inputs are described in RPP-CALC-63247.

3.4.2 Calculations

The **Risk_Calculations** container (Figure 3-7) holds the **Dermal_Absorbed_Dose** container, six expression elements and two summary elements for calculating both the cancer risk and non-cancer HQ for the residential tap water scenario.

The **Dermal_Absorbed_Dose** container holds the **DAevent_nc** and **DAevent_c** expressions. **DAevent_nc** calculates the dermal absorbed dose from contact with non-carcinogenic hazardous substances in tap water (Equation 3-7) for use in calculating the non-cancer hazards of dermal contact with chemicals (Equation 3-6, GoldSim© element **HQ_tw_dermal**). The output is a matrix of type "Chemicals" by type "Tanks" and the expression's inputs are **Kp**, **GW_Concentration_Data** and **t_event_rc**. **DAevent_c** calculates the dermal absorbed dose from contact with carcinogenic hazardous substances in tap water (Equation 3-7) for use in calculating the cancer risk of dermal contact with chemicals (Equation 3-4, GoldSim© element **Risk_tw_dermal**). The output is a matrix of type "Chemicals" by type "Tanks" and the expression's inputs are **Kp**, **GW_Concentration_Data** and **t_event_adjr.**

Cancer Risk Calculations. **Risk_NonRad_Ingestion** calculates the cancer risk from ingestion of hazardous substances in tap water (Equation 3-1). The output is a matrix of type "Chemicals" by type "Tanks" and the expression's inputs are **GW_Concentration_Data**, **EF_r**, **IRW_radj_nonrad**, **SFo** and **AT_c**.

Risk_tw_dermal calculates the cancer risk from contact with hazardous substances in tap water (Equation 3-4). The output is a matrix of type "Chemicals" by type "Tanks" and the expression's inputs are **DAevent_c**, **EF_r**, **EV_r**, **SA_radj**, **SFo**, **GIABS_CHEM** and **AT_c.**

Risk_tw_nonrad_inhalation calculates the risk from inhalation of volatile hazardous substances in tap water (Equation 3-10). The output is a matrix of type "Chemicals" by type "Tanks" and the expression's inputs are **Volatiles_Concentration**, **EF_r**, **ED_r**, **ET_r**, **K**, **IUR** and **AT_c**. **Volatiles_Concentration** screens out non-volatile chemicals from **GW_Concentration_Data** by multiplying them by **Volatility_Screen** (**\Exposure_Scenarios \Residential_Tap_Water_Scenario\Species_specific_parameters\Volatility_Screen**).

TW_Sum_Risk_NonRads sums the contributions from **Risk_NonRad_Ingestion**, **Risk_tw_dermal** and **Risk_tw_nonrad_inhalation**, and outputs the result into a matrix of type "Chemicals" by type "Tanks" (Equation 3-12).

NonRad_Risk_Total_By_Source sums the cancer risks for each contaminant calculated by **TW_Sum_Risk_NonRads** for each tank. It outputs the result into a vector of type "Tanks" (Equation 3-13).

A_NonRad_Risk_Total_By_Analyte sums the cancer risks for each contaminant from all A Farm tanks into a vector of type "Chemicals". The expression's input is the matrix of results from **TW_Sum_Risk_NonRads** and is summed over all sources in A Farm.

AX_NonRad_Risk_Total_By_Analyte sums the cancer risks for each contaminant from all AX Farm tanks into a vector of type “Chemicals”. The expression’s input is the matrix of results from **TW_Sum_Risk_NonRads** and is summed over all sources in AX Farm.

NonRad_Risk_Total_By_Analyte sums the cancer risks for each contaminant in each WMA A-AX tank into a vector of type “Chemicals”. The expression’s input is the matrix of results from **TW_Sum_Risk_NonRads** summed over all sources in WMA A-AX.

A_NonRad_Total_Risk calculates the cumulative cancer risk from all chemicals in all tanks in A Farm and returns a scalar value. The expression’s input is the vector of results from **A_NonRad_Risk_Total_By_Analyte** (Equation 3-13).

AX_NonRad_Total_Risk calculates the cumulative cancer risk from all chemicals in all tanks in AX Farm and returns a scalar value. The expression’s input is the vector of results from **AX_NonRad_Risk_Total_By_Analyte** (Equation 3-13).

Total_NonRad_Risk calculates the cumulative cancer risk from all chemicals in all tanks in WMA A-AX and returns a scalar value. The expression’s input is the vector of results from **NonRad_Risk_Total_By_Analyte** (Equation 3-13).

3.4.2.1 Non-Cancer Hazard Calculations. HQ_non_rad_ingestion calculates the non-cancer hazard from ingestion of hazardous substances in tap water (Equation **3-3**). The output is a matrix of type “Chemicals” by type “Tanks” and the expression’s inputs are **GW_Concentration_Data**, **EF_r**, **IRW_rc**, **ED_rc**, **BW_c**, **AT_nc** and **RfDo**.

HQ_tw_dermal calculates the non-cancer hazard from contact with hazardous substances in tap water (Equation 3-6). The output is a matrix of type “Chemicals” by type “Tanks” and the expression’s inputs are **DAevent_nc**, **EF_r**, **EV_r**, **SA_rc**, **ED_rc**, **AT_nc**, **BW_c**, **RfDo** and **GIABS_CHEM.**

HQ_tw_nonrad_inhalation calculates the non-cancer hazard from inhalation of volatile hazardous substances in tap water (Equation 3-11). The output is a matrix of type “Chemicals” by type “Tanks” and the expression’s inputs are **Volatiles_Concentration**, **EF_r**, **ED_rc**, **ET_r**, **K**, **AT_nc** and **RfCi**. **Volatiles_Concentration** screens out non-volatile chemicals from **GW_Concentration_Data** by multiplying them by **Volatilty_Screen** (**\Exposure_Scenarios\Residential_Tap_Water_Scenario\Species_specific_parameters\Volatility_Screen**).

TW_Sum_HQ_NonRads sums the contributions from **HQ_non_rad_ingestion**, **HQ_tw_dermal** and **HQ_tw_nonrad_inhalation**, and outputs the result into a matrix of type “Chemicals” by type “Tanks” (Equation 3-14).

NonRad_HI_By_Source sums the HQs for each contaminant calculated by **TW_Sum_HQ_NonRads** for each tank. It outputs the result into a vector of type “Tanks” (Equation 3-15).

A_NonRad_HQ_Total_By_Analyte sums the HQs for each contaminant from all A Farm tanks into a vector of type “Chemicals”. The expression’s input is the matrix of results from **TW_Sum_HQ_NonRads** and is summed over all sources in A Farm.

AX_NonRad_HQ_Total_By_Analyte sums the HQs for each contaminant from all AX Farm tanks into a vector of type “Chemicals”. The expression’s input is the matrix of results from **TW_Sum_HQ_NonRads** and is summed over all sources in AX Farm.

NonRad_HQ_Total_By_Analyte sums the HQs for each contaminant in each WMA A-AX tank into a vector of type “Chemicals”. The expression’s input is the matrix of results from **TW_Sum_HQ_NonRads** and is summed over all sources in WMA A-AX.

A_Total_HI calculates the HI from all tanks in A Farm and returns a scalar value. The expression’s input is the vector of results from **A_NonRad_HQ_Total_By_Analyte** (Equation 3-15).

AX_Total_HI calculates the HI from all tanks in AX Farm and returns a scalar value. The expression’s input is the vector of results from **AX_NonRad_Risk_Total_By_Analyte** (Equation 3-15).

Total_HI calculates the HI from all tanks in WMA A-AX and returns a scalar value. The expression’s input is the vector of results from **NonRad_HQ_Total_By_Analyte** (Equation 3-15).

3.4.2.2 Sensitivity Calculations. Sensitivity analysis-related calculations are described in RPP-CALC-63247.

4.0 ASSUMPTIONS AND INPUTS

RPP-RPT-60885 lists assumptions and inputs for the groundwater pathway calculations. Inventory-related assumptions are detailed in RPP-CALC-62319. Pipeline inventories assumptions are discussed in RPP-RPT-58293. The EPA tap water scenario assumptions are detailed in RPP-ENV-58813.

4.1 KEY ASSUMPTIONS

Key general assumptions used in the model are detailed in RPP-RPT-60885, and are as follows.

- The landfill closure of WMA A-AX is assumed to occur at year 2050.
- It is assumed that institutional control and societal memory is retained for the first 100 years after the year of closure.
- WMA A-AX tanks (except for 241-A-104 [A-104] and 241-A-105 [A-105]) are assumed to be retrieved and filled with grout.
- Pipelines in WMA A-AX are not grouted and are 5% full of waste, evenly distributed throughout the pipeline.
- The modified RCRA Subtitle C barrier functions according to its design specifications for 500 years.

Key groundwater transport and recharge assumptions used in the analysis are as follows (RPP-RPT-60885).

- A vegetation cover representative of natural conditions is assumed over the whole domain during the pre-operations period.
- During the construction and operations period, the following covers are assumed:
    - The undisturbed zone around the facility characterized by a native vegetation cover
    - The disturbed zone around the facility that has scant deep-rooted vegetation but extensive grass cover, combined with the resurfaced zone around the facility that has no vegetation cover
    - The tank farm zone where gravel backfill is kept free of vegetation.
- During the early post-closure period, the following covers are assumed:
    - The zone beneath the extent of the A Complex surface barrier that is designed to minimize infiltration of meteoric waters

  - The disturbed/resurfaced zone, outside the surface barrier, characterized by an artificially-introduced vegetation cover attempting to reclaim the surface with native vegetation species.

- The impact of the closure barrier on moisture flow is approximated by an assumed recharge rate into the facility.

- Net infiltration through the thick, heterogeneous vadose zone in the 200 Areas dampens the effect of discrete events, and therefore episodic precipitation events can be replaced by an average annual recharge rate.

- The porous media continuum assumption (an extended form of Darcy's Law for vadose zone applications) and the soil relative permeability/saturation/capillary pressure relations provide the basis for vadose zone flow and transport modeling.

- The vadose zone is modeled as an aqueous-gas porous media system where flow and transport through the gas phase are assumed to be negligible.

- For the pipeline source areas, the aquifer pathway begins at the center of the A Farm area and the AX Farm area to account for some vadose zone contribution occurring earlier.

- Hydraulic property heterogeneity is assumed to be insignificant within geologic units. Hence, each geologic unit within the vadose zone is assigned upscaled, effective hydraulic properties.

- The POCs used in the calculation of the groundwater concentrations correspond to 1) the WMA fenceline and 2) the location 100 m (328 ft) downgradient from the facility. For calculating groundwater concentrations to compare with groundwater protection requirements, it is necessary to identify the peak location in space at which the concentration occurs.

Assumptions about the residual waste form are detailed in RPP-RPT-60885, while inventory-related assumptions are detailed in RPP-CALC-62319. Key residual waste assumptions used in the model are:

- Due to the lack of characterization data on WMA A-AX residual waste, most of the residual waste characteristics are assumed to be the same as WMA C residual waste

- The unretrieved wastes are assumed to be distributed uniformly throughout the bottom area of the waste source

- Residual waste volumes for all tanks, except A-104 and A-105, are assumed to be 360 ft^3

- Residual waste volumes for tanks A-104 and A-105 are those found in the current BBI

- Current BBI concentrations are used for tank inventory estimates due to lack of specific retrieval information

- Pipeline inventories are developed using the Hanford Tank Waste Operations Simulator (HTWOS) (RPP-RPT-58293) because flushed pipelines are assumed to have similar residual concentrations as retrieved tanks

- Although some of the ancillary equipment may be grouted consistent with 78 FR 75913, "Record of Decision: Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington," it is assumed for the purpose of the analysis that none of the ancillary equipment is grouted, and the presence of pipeline walls and encasements is ignored, such that releases from ancillary equipment are primarily controlled by advection.

The estimated volume of waste in pipelines is uncertain. An effort was made to provide a conservative estimate (RPP-RPT-58293). Limited pipeline investigations in other tank farms have indicated that the lines should be flushed. While none of the WMA A-AX pipelines are known to be plugged, the possibility of a plug exists. There is also the possibility that some of the lines in WMA A-AX may not be well flushed. Overall, a 5% estimate is believed to be high; pipelines studied in 241-SY Tank Farm showed no discernable waste and about 4% of the pipe volume contained waste in 15- to 18-in. vitrified clay pipes between the 231-Z building and Z ditches (RPP-RPT-58293).

Key assumptions about the closed waste form include the following (RPP-RPT-60885).

- The chemical effect of the grout is represented by contaminant-specific distributions of distribution coefficients (K_d), which have been developed from international literature on sorption of radionuclides on cementitious materials. These values are generally consistent with, or lower than, comparable values used for the facility-specific grout at the Savannah River F and H tank farm performance assessments [WSRC-STI-2007-00369, *Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure* and WSRC-STI-2007-00607, *Chemical Degradation Assessment of Cementitious Materials for the HLW Tank Closure Project (U)*].

- Because the closed tanks are in the unsaturated zone, conditions are expected to be moderately oxidizing. When data are available to differentiate between oxidizing and reducing conditions, oxidizing conditions are assumed. This approach leads to selecting lower K_d values in the model.

- The selected K_d values are based on the assumption of $Ca(OH)_2$-saturated waters contacting the waste.

- Grout is likely to provide a significant barrier to infiltrating water, thus limiting any water flow through the tank and thereby restricting the release from the residual waste to be diffusion-controlled.

- The presence of continuous water connections is assumed across the grout and concrete layers for the diffusive transport to occur in the aqueous phase.

Exposure routes evaluated for the tap water exposure pathway under a residential exposure scenario are ingestion, inhalation, and dermal absorption. For domestic use of groundwater as a drinking water supply, EPA considers the inhalation pathway potentially complete only for volatile contaminants, because there is no mechanism for release of nonvolatile chemicals into the air in significant concentrations [EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) Interim*]. For the tap water exposure pathway, inhalation intake is quantified only for volatile contaminants, as defined by EPA (EPA Home | Risk Assessment | Regional Screening Levels (RSLs) | Generic Tables).

4.2 INPUTS

Inputs for this calculation include residual waste inventories, tap water scenario parameters and contaminant-specific factors related to tap water scenario exposure pathways. Table 4-1 lists the inputs, their sources and the attachments to this document that list their values.

Table 4-1. Inputs Used in the Residential Tap Water Scenario Model.

Input	Reference	Attachment
Inventory	RPP-CALC-62319, *Residual Waste Source Inventory Term for the Waste Management Area A-AX Performance Assessment Inventory Case 1* (tank inventories); RPP-RPT-58293, *Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates* (non-tank source inventories).	2
Residential tap water scenario general parameters	RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*	3
Residential tap water scenario contaminant specific-parameters	RPP-ENV-58806, *RCRA Closure of Tank Waste Residuals Impacts at Waste Management Area C, Hanford Site, Washington*	4

5.0 SOFTWARE APPLICATIONS

The software used to perform this calculation are approved, managed, and used in compliance with the CH2M HILL Plateau Remediation Company (CHPRC) requirements of PRC-PRO-IRM-309, “Controlled Software Management.”

5.1 SOFTWARE IDENTIFICATION

Software is registered on the Hanford Information System Inventory and is identified as approved for use. The identification for the software package used in the calculation is as follows:

- GoldSim© Pro
- Version 12.0
- Hanford Information System Inventory Identification Number: 2461
- Workstation type and property number: Dell™ Optiplex™[14] 7040 (WF34039).

5.2 SOFTWARE QUALITY ASSURANCE

All calculations are performed using GoldSim© Pro simulator software, Version 12.0. GoldSim© Pro simulator is approved for use by CHPRC at the Hanford Site in accordance with the requirements of PRC-PRO-IRM-309. WRPS recognizes CHPRC’s role as Hanford Site environmental modeling integrator (TFC-PLN-155, “General Project Plan for Environmental Modeling”) and accepts CHPRC’s qualification of GoldSim© Pro. The installed GoldSim© Pro simulator software was tested in accordance with the procedure per CHPRC-00175, *GoldSim Pro Software Management Plan*, Rev. 3, using CHPRC-00224, *GoldSim Pro Software Test Plan*, Rev. 2.

5.3 SOFTWARE INSTALLATION AND CHECKOUT

The software installation and checkout form for GoldSim© is provided in Attachment 1 to this EMCF.

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[14] Dell™ and Optiplex™ are trademarks of Dell Inc., Round Rock, Texas.

5.4 STATEMENT OF VALID SOFTWARE APPLICATION

The following verifies that GoldSim© is a valid software application and was applied in this EMCF within its range of intended uses for which it was tested and approved.

- GoldSim© Pro was utilized for DOE to assist in performing simulation of contamination mass transport in subsurface environment, and perform human health risk assessment for the Hanford Site.

- GoldSim© Pro as it is used in this EMCF has been implemented within the range of its limitations.

6.0 CALCULATION

The calculations are performed with GoldSim© using the named a_ax v1.0_20190813_Tap_Water_Scenario.gsm model file. Sensitivity calculations were performed using the models listed in Table 6-1.

Table 6-1. Model Files Used for the Sensitivity Analyses.

Sensitivity Case	Model File
Surface Barrier	EMCF-62538_INF.gsm
Inventory	a_ax v1.0_20190408_INV_0_1_2(b).gsm
Grout	a_ax v1.0_20190408_GRT_BM_TS.gsm
Tank Shell	a_ax v1.0_20190408_GRT_BM_TS.gsm
Base Mat	a_ax v1.0_20190408_GRT_BM_TS.gsm

These model files are reviewed and checked and will be archived in Environmental Model Management Archive (EMMA) along with this EMCF and other supporting files.

6.1 DESCRIPTION OF MODEL CHANGES

This model uses the model described in RPP-RPT-60885 as its basis. This model file was created from the version-controlled “a_ax v1.0_20190408.gsm” model file by performing the following.

- Adding chemical inventories (Attachment 2) to the **Inventories** container.

- Configuring the **SZ_100m_Conc** container as detailed in Section 3.4.

- Configuring the **Residential_Tap_Water_Scenario** container as detailed in Section 3.4.

- Adding expression and time history result elements in **\Transport_Abstraction_Model\SZ_100m_Conc** to display groundwater concentration results for each chemical with a non-zero inventory and K_d less than or equal to 0.6 mL/g. These are:
    - **Cr_concentrations_by_source**
    - **Cr_Conc_by_source_chart**
    - **F_concentrations_by_source**
    - **F_Conc_by_source_chart**
    - **NO3_concentrations_by_source**
    - **NO3_Conc_by_source_chart**
    - **NO2_concentrations_by_source**
    - **NO2_Conc_by_source_chart**
    - **U_concentrations_by_source**

  - **U_Conc_by_source_chart**
  - **Cr6_concentrations_by_source**
  - **Cr6_Conc_by_source_chart**.

- Adding time history elements to compare dissolved concentrations for nitrate and chromium in tank A-105 to **\Transport_Abstraction_Model\Transport_A_Series_Tanks**. These are:
  - **NO3_Diss_Conc_Comparison_A105**
  - **Cr_Diss_Conc_Comparison_A105**.

- Adding expression and time history result elements in **\Transport_Abstraction_Model\Source_Release_To_VZ** to display the release of chromium and nitrate to the vadose zone from each source. These are:
  - **Cr_Release_To_VZ**
  - **Cr_Release_To_VZ_Chart**
  - **NO3_Release_To_VZ**
  - **NO3_Release_To_VZ_Chart**

- Adding a data element (**\Exposure_Scenarios\Residential_Tap_Water_Scenario \Species_specific_parameters\Volatility_Screen**) which contains a multiplier to screen out non-volatile chemicals from the inhalation calculations (0 if non-volatile, 1 if volatile).

- Adding scenarios for cancer risk and non-cancer hazard calculations at 1) the WMA fenceline, and 2) 100 m downgradient from the WMA fenceline. The GoldSim© Scenario Manager allows a user to run multiple scenarios at the same time that have different values for data elements. The Scenario Manager in this model facilitates direct comparison of the results from both scenarios. Both scenarios in this model use the **\Exposure_Scenarios\Residential_Tap_Water_Scenario\GW_Concentrations** element which contains the groundwater concentration over time data relevant to the chosen scenario:

  - For the WMA fenceline case, the **Fenceline_switch** element is set to true, which copies groundwater concentration data in **\Transport_Abstraction_Model\SZ_Fence_Conc\Chem_Fenceline_Conc** to the **GW_Concentrations** element

  - For the 100-m case, the **Fenceline_Switch** element is set to false, which copies groundwater concentration data in **\Transport_Abstraction_Model\SZ_100m_Conc\Chem_100m_Conc** to the **GW_Concentrations** element.

Additionally, all elements for intruder dose calculations, groundwater dose calculations and radionuclide concentration reporting were removed as they are irrelevant to calculating cancer risks and non-cancer hazards from chemicals.

When using GoldSim's$^{©}$ Scenario features, there is a temporary placeholder model—known as a "live" model—that can be configured outside of the saved scenarios. Several of the results elements will only work in the live model:

- **\Transport_Abstraction_Model\Source_Release_To_VZ \NO3_Release_To_VZ_Chart**
- **\Transport_Abstraction_Model\Source_Release_To_VZ\Cr_Release_To_VZ_Chart**
- **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_Concentrations_Fenceline**
- **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_Concentration_Year_Fencel**
- **\Transport_Abstraction_Model\SZ_100m_Conc\Peak_Concentrations_100m**
- **\Transport_Abstraction_Model\SZ_100m_Conc\Peak_Concentration_Year_100m**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \NonRad_HI_Peak_Time_by_Source**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations \A_Total_HI**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations \AX_Total_HI**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \A_NonRad_HQ_Peak_by_Analyte**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \A_NonRad_HQ_Peak_Time_by_Analy**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations \A_Total_HI**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \A_NonRad_HQ_Peak_by_Analyte**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \A_NonRad_HQ_Peak_Time_by_Analy**
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations \A_Total_HI**

- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \AX_NonRad_HQ_Peak_by_Analyte**

- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \AX_NonRad_HQ_Peak_Time_by_Ana**

- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations \AX_Total_HI**

- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \AX_NonRad_HQ_Peak_by_Analyte**

- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results \AX_NonRad_HQ_Peak_Time_by_Ana**

- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations \AX_Total_HI**.

In order to access these results, the live model can be configured to calculate risk and hazard calculations using either fenceline or 100-m downgradient groundwater concentrations by manually changing the value in the **Fenceline_switch** element to either true (for fenceline) or false (for 100-m).

For the sensitivity cases, each model file had the following results elements added.

- **\Transport_Abstraction_Model\SZ_100m_Conc\combined_100m_Afarm\ Total_Chem_Conc_100m_A**: Sums the concentrations of each chemical 100 m downgradient from the facility across all A Farm tanks.

- **\Transport_Abstraction_Model\SZ_100m_Conc\combined_100m_Afarm\ A_NO2_100m_Conc**: Time series element showing the concentration of nitrite from all A Farm tanks at 100 m downgradient from the facility over time.

- **\Transport_Abstraction_Model\SZ_100m_Conc\combined_100m_AXfarm\ Total_Chem_Conc_100m_AX**: Sums the concentrations of each chemical 100 m downgradient from the facility across all AX Farm tanks.

- **\Transport_Abstraction_Model\SZ_100m_Conc\combined_100m_AXfarm\ AX_NO2_100m_Conc**: Time series element showing the concentration of nitrite from all AX Farm tanks at 100 m downgradient from the facility over time.

Additionally, the file a_ax v1.0_20190408_GRT_BM_TS.gsm had the following results element added:

- **\Transport_Abstraction_Model\SZ_100m_Conc\combined_100m_Afarm\A_Tc_100m_Conc:** Time series element showing the concentration of technetium from all A Farm tanks at 100 m downgradient from the facility over time.

6.1.1 Model Configuration Control

All inputs and outputs for the development of the WMA A-AX PA GoldSim©-based system model are archived to the CHPRC EMMA to maintain and preserve models, input and select output files under configuration management. Inputs include the input files used in the GoldSim© simulations and the input parameters. Basis information (that information collected to form the basis for model input parameterization) is also stored in the EMMA for traceability purposes.

6.1.2 Model Checking

The WMA A-AX GoldSim© system model is checked using the procedure found in Section 4.2.2 of TFC-ESHQ-ENV_FS-C-05, "Preparation and Issuance of Model Package Reports and Environmental Model Calculation Files." The model checker was provided with:

- the versioned copy of the GoldSim© model files ["a_ax v1.0_20190813_Tap_Water_Scenario.gsm", "a_ax v1.0_20190408_INV_0_1_2(b).gsm", "a_ax v1.0_20190408_GRT_BM_TS.gsm", "EMCF-62538_INF.gsm"]

- A copy of the MPR (RPP-RPT-60885)

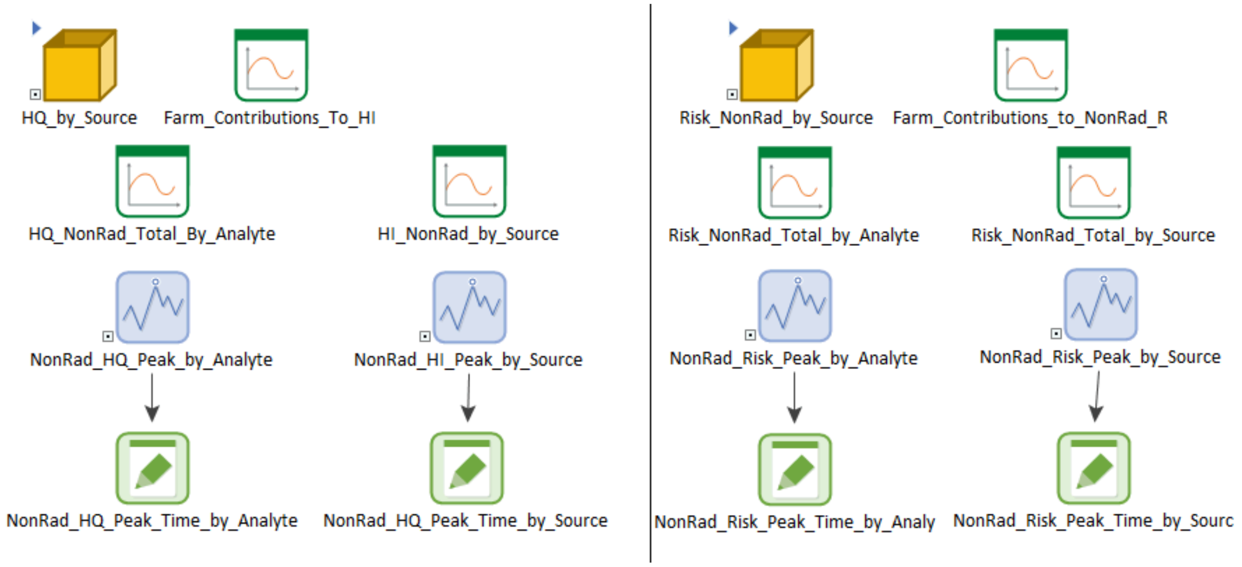
- A draft copy of this EMCF.

The checker made comments and all comments were resolved as indicated by a signed checker's log.

6.2 DESCRIPTION OF CALCULATED OUTPUT

Calculated output is contained in the **Risk_Calculation_Results** container (Figure 6-1). There are two child containers which tabulate the HQ and cancer risk results by source. For HQ (**HQ_by_Source**), there is one vector per tank of HQ by chemical, and one time-series chart per tank of HQ by chemical. The output of these calculations is a series of data matrices. Cancer risk results (**Risk_NonRad_by_Source**) are configured the same way. The results will not be presented in this much detail in this EMCF.

Figure 6-1. Contents of the Risk_Calculation_Results Container of the Waste Management Area A-AX System Model for Calculating the Residential Tap Water Scenario.



Besides the source-level result containers, **Risk_Calculation_Results** contains seven result elements both for cancer risk results and non-cancer hazard results:

- For each metric, there are three time-series charts that present the results by analyte over the entire WMA, by each source in the WMA, and each farm's contribution to the results of the entire WMA
- For each metric, there are two maxima, which find the peak result by analyte and the peak result by source
- For each metric, there are two tables which contain the year in which the peak results occurred both by analyte and by source.

For non-time-series results (such as maxima), the results are captured at the end of the 10,000-year simulation. In addition, a time point was added in the model to capture and report results at 1,000 years post-closure.

7.0 RESULTS AND CONCLUSIONS

This section presents the results of modeling groundwater transport at WMA A-AX in terms of contaminant concentrations along with the results of the cancer risk and non-cancer hazard calculations for the closed WMA A-AX using the residential tap water exposure scenario. For carcinogens, the target risk level is 1×10^{-6} with a target cumulative risk level of 1×10^{-5}. For noncarcinogens the target is an HQ of 1 and an HI of 1. Results are presented for two time periods: the 0- to 1,000-year period (2050 to 3050) and 1,000- to 10,000-year period post-closure. Results are provided for the receptor located 100 m (328 ft) downgradient from the WMA A-AX fenceline.

7.1 RESULTS

7.1.1 Source Term

The source term is defined as the rate of release from WMA A-AX tanks and ancillary equipment as a function of time (NCRP Report No. 152, *Performance Assessment of Near-Surface Facilities for Disposal of Low-Level Radioactive Waste*). Since it is defined as a release from the facility, it includes a number of processes associated with mobilization of contaminants from the waste form, and migration of the contaminants to the boundary of the facility. The boundary of the facility for WMA A-AX source term is considered the outer boundary of the engineered features (i.e., the bottom of the tank base mat, or the outer surface of pipelines and other ancillary equipment). The source term and how it is modeled is detailed in RPP-RPT-60885.

Figure 7-1 presents the release rate for nitrate from each of the sources in the source term. An initial large release rate occurs for the pipeline source, which is attributable to the assumption that releases from the pipelines are dominated by advection. The sharp decline in the pipeline release rate reflects source inventory depletion, and—to a lesser extent—the declining flow rate as the system responds to the installation of the cover, when the recharge rate drops to 0.5 mm/yr (0.02 in./yr). Nearly the entire nitrate inventory associated with the pipeline source term is released by about 50 years after closure. In contrast, the release rate from the grouted tanks increases gradually, because of the slower diffusive transport through the base mat.

The magnitude of the diffusive release rates from each source are proportional to the residual concentration of nitrate (residual inventory per unit residual water volume) within each source. The release rate from tank 241-A-101 (A-101) remains the highest in the first 127 years because of its highest residual concentration of nitrate. However, the release rate of tank A-105 becomes highest after 127 years as the release rate from tank A-101 declines. This is primarily due to a larger residual nitrate inventory in tank A-105 (9,530 kg) compared to tank A-101 (2,400 kg). Note that the initial residual waste volume of tank A-105 is larger (139,000 L) than that of tank A-101 (10,194 L) and therefore, even though the inventory is larger in tank A-105, it leads to a smaller initial concentration compared to tank A-101. Also, note that the residual nitrate inventory in tank 241-AX-101 (2,560 kg) is larger than that of tank A-101 (2,400 kg), but has a lower release rate (2,311 g/yr at 100 years post-closure) than tank A-101 (2,804 g/yr at 100 years post-closure). This is because there is a longer diffusion length through the base of the AX Farm tanks (17.5 in.) than through the base of the A Farm tanks (8 in.). This difference in diffusion lengths also results in a longer release time for AX Farm tanks than for A Farm tanks within the model time frame. The small rise in release rate noticeable at about 500 years is due to an increase in Darcy flux, when the surface barrier is assumed to transition to its degraded state and the recharge rate changes from 0.5 mm/yr to 3.5 mm/yr.

Figure 7-2 compares the concentrations resulting from the release of nitrate from the waste layer to the tank base mat for a representative tank (tank A-105). There is a sharp initial spike in concentration in the tank base mat as mass moves from the residual waste layer and concentration gradient is established. The concentrations gradually decline as mass is depleted due to continuous diffusive release. Release from other tanks are similar; however, the differences in magnitudes are due to differences in starting inventory.

The release rate for chromium from all sources at WMA A-AX is presented in Figure 7-3. The source term release is based on observed high value tank 241-C-202 leachate (RPP-RPT-60885). Chromium has a dissolved concentration limit of 2,000 µg/L in all sources except the non-tank sources. As a result, a sharp decline in the release is observed for the non-tank sources after 500 years post-closure as the inventory is depleted through advection with the higher Darcy flux assumed after the barrier degrades.

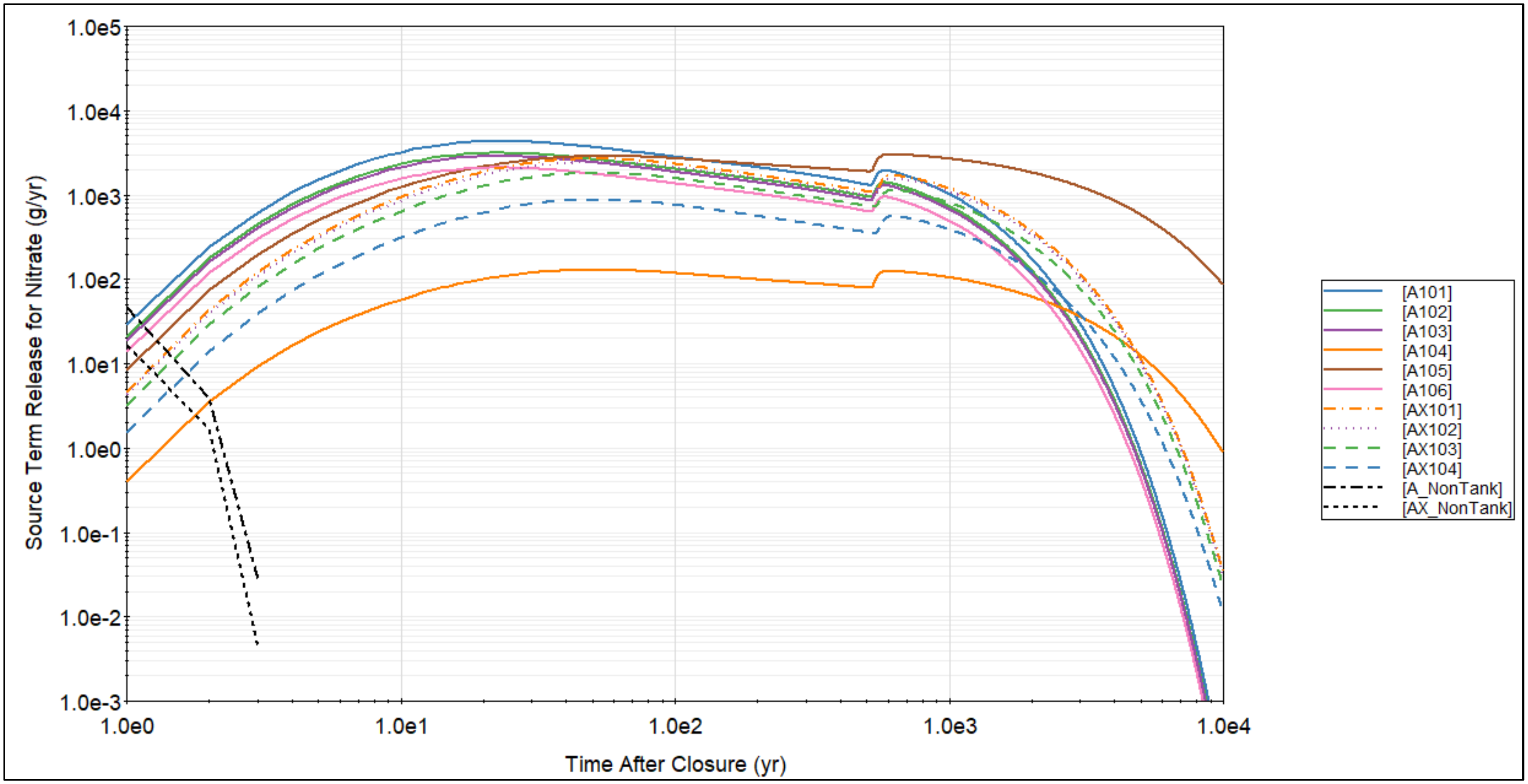
The dissolved concentration for chromium in tank A-105 is shown in Figure 7-4 exiting the residual waste and the tank bottom. The concentration in the residual waste remains at the solubility limit, indicating that inventory remains in the tank at the end of the simulation. The dissolved chromium concentration in the tank base mat remains slightly lower than the residual waste, reflecting the diffusion gradient to the outside of the tank.

7.1.2 Groundwater Concentrations of Chemicals

This section presents the groundwater concentration results from modeling subsurface transport of chemicals. The results are presented for two time periods: 1) from closure to 1,000 years post-closure and 2) from 1,000 to 10,000 years post-closure. Tabular and graphical presentations of the summaries of the various transport calculations are presented.

Table 7-1 presents the maximum concentrations in groundwater of each chemical with a non-zero inventory in the residual waste in A Farm and Table 7-2 shows the same for AX Farm. The concentrations are calculated at both the WMA fenceline and 100 meters downgradient from the WMA A-AX fenceline and are presented along with their K_d values (in sand) and applicable Federal and State maximum contaminant levels (MCLs). Note that K_d values in sand are provided as an example and chemical K_ds in gravel and silt may be different than in sand, resulting in different rates of adsorption as the chemicals move through stratigraphic units containing these sediment types.

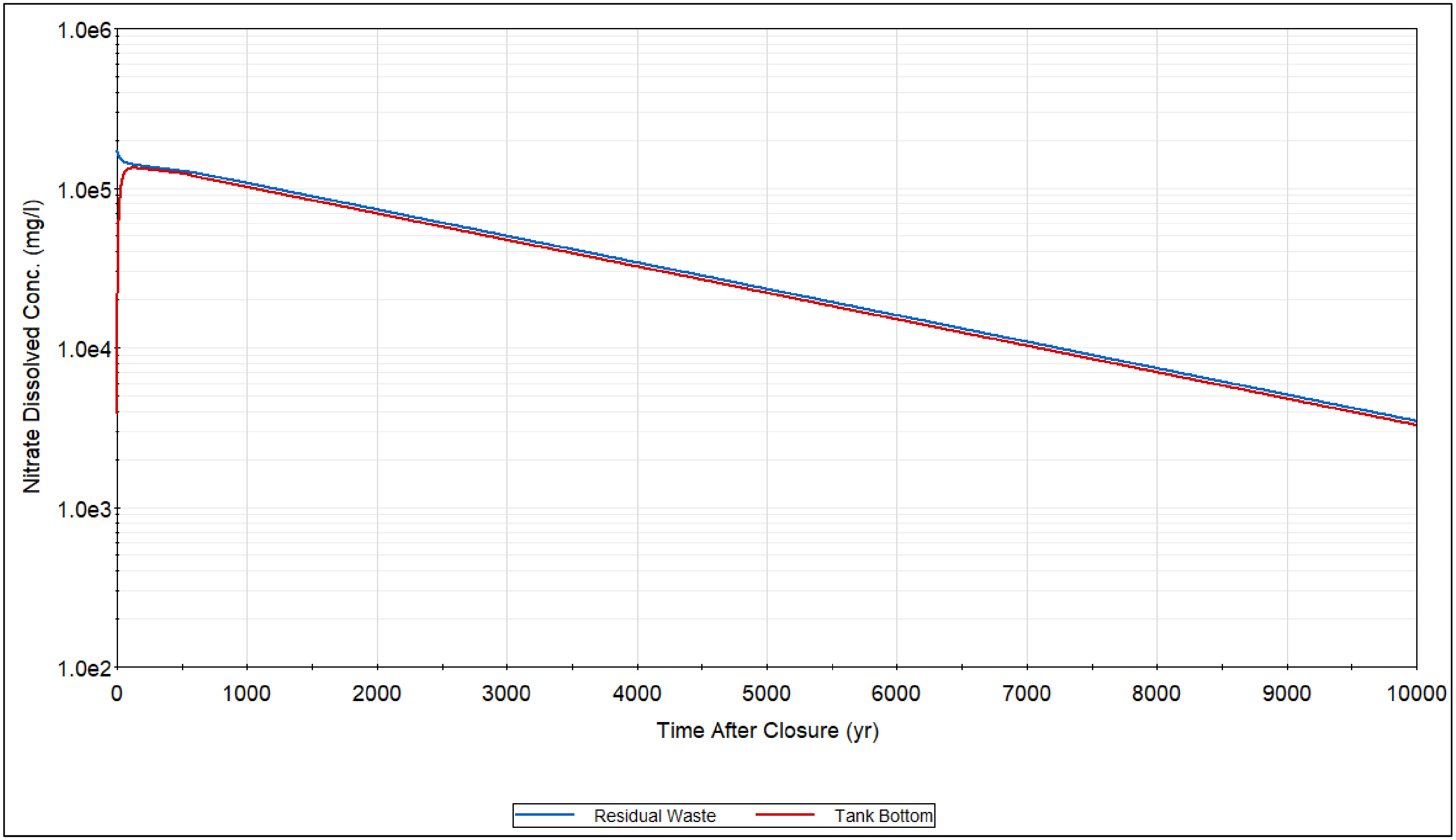
Figure 7-1. Release Rate of Nitrate (grams per year) from Each Source at Waste Management Area A-AX.



GoldSim© element: \Transport_Abstraction_Model\Source_Release_To_VZ\NO3_Release_To_VZ_Chart.

GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

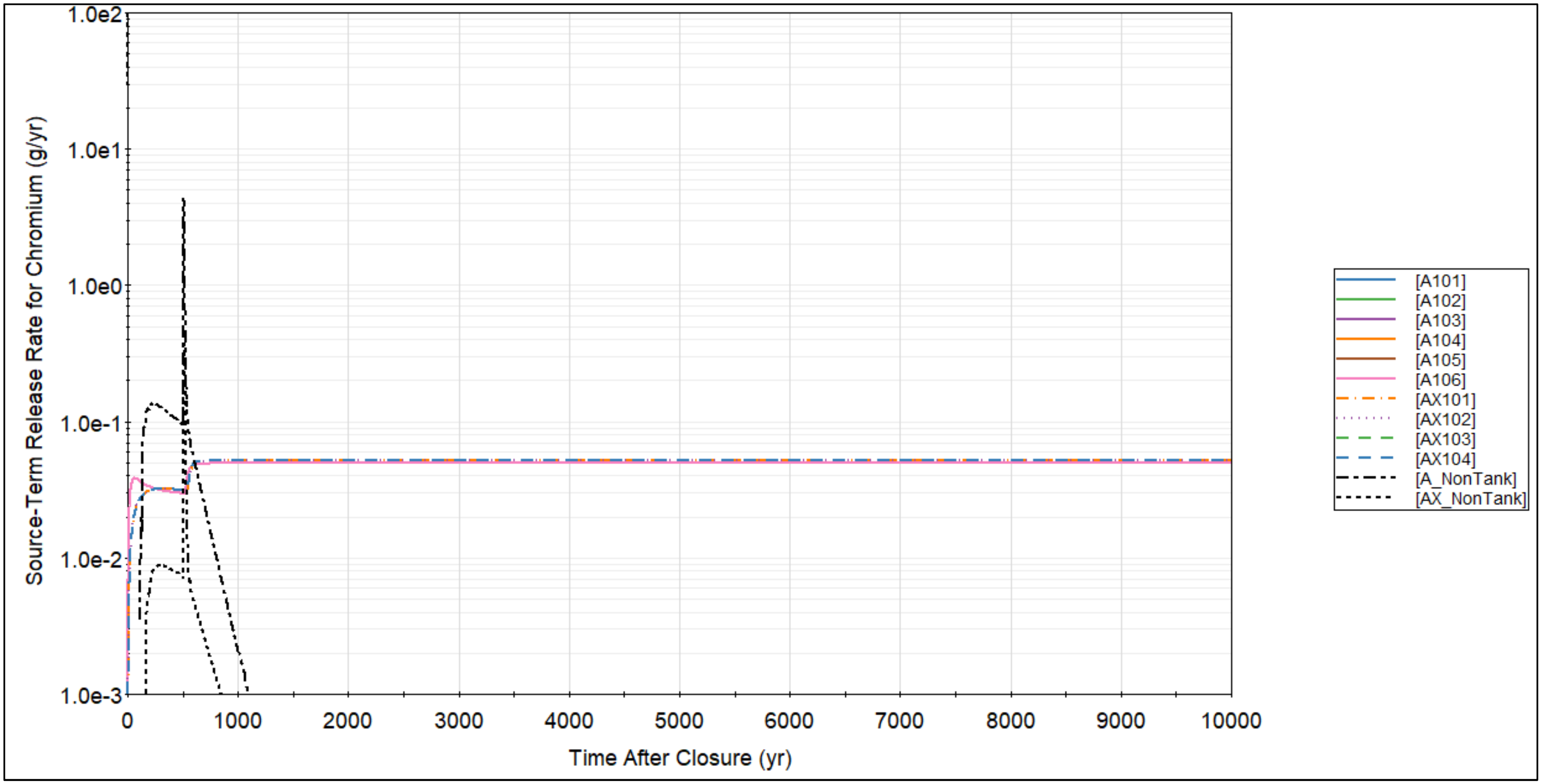
Figure 7-2. Comparison of Dissolved Concentrations of Nitrate (milligrams per liter) in the Residual Waste and Tank Bottom for Tank 241-A-105.



GoldSim© Element: \Transport_Abstraction_Model\Transport_A_Series_Tanks\NO3_Diss_Conc_Comparison_A105.

GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

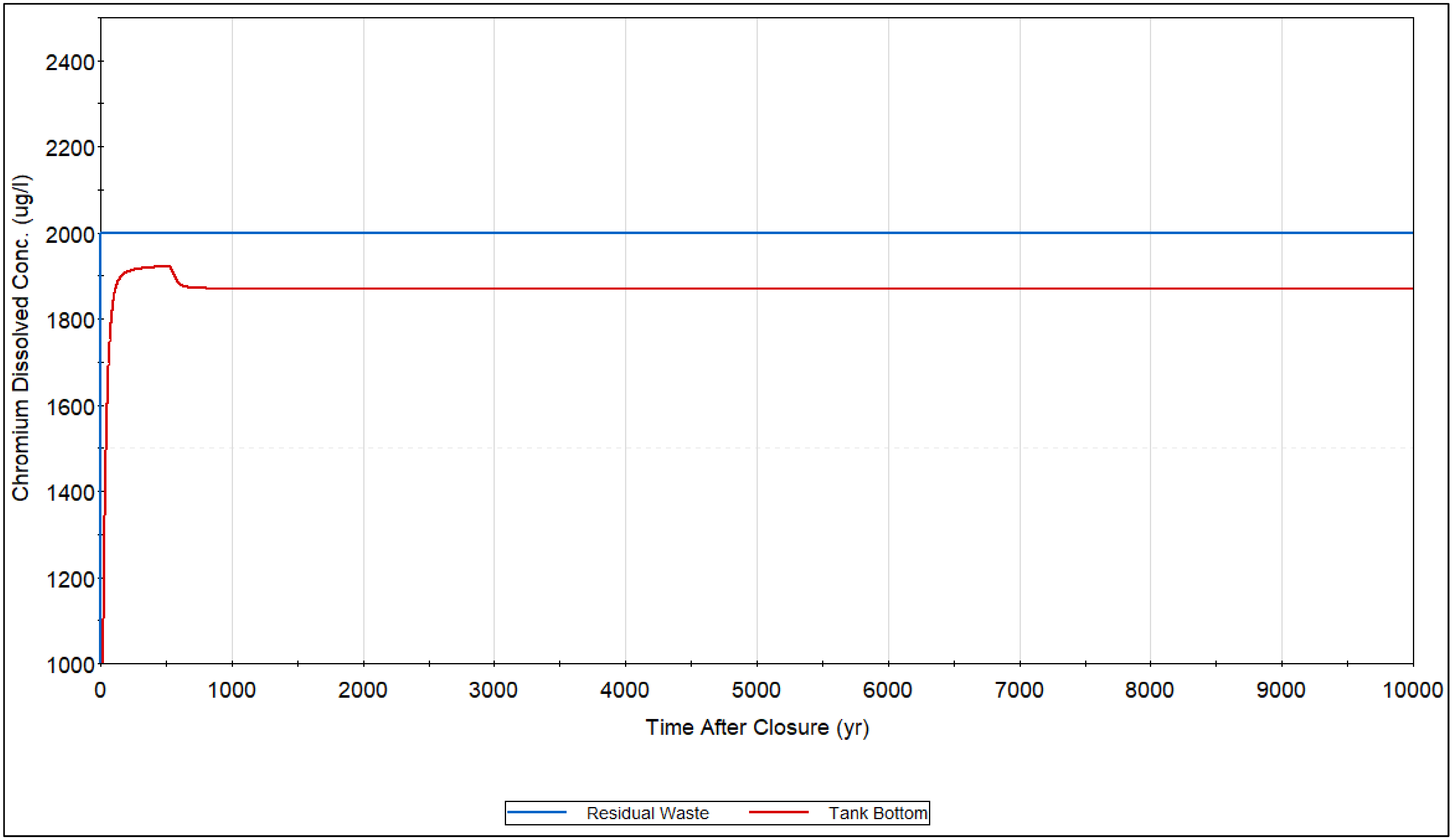
Figure 7-3. Release Rate of Chromium (grams per year) from All Sources at Waste Management Area A-AX.



GoldSim© Element: \Transport_Abstraction_Model\Source_Release_To_VZ\Cr_Release_To_VZ_Chart.

GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

Figure 7-4. Comparison of Dissolved Concentration of Chromium (micrograms per liter) in the Residual Waste and Tank Bottom for Tank 241-A-105.



GoldSim© Element: \Transport_Abstraction_Model\Transport_A_Series_Tanks\Cr_Diss_Conc_Comparison_A105.

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Table 7-1. Maximum Groundwater Concentration for All Chemicals with Inventories Greater than Zero in A Farm at 100 meters Downgradient from Waste Management Area A-AX over the 0- to 1,000-year and 1,000- to 10,000-year Post-Closure Time Frames.

Chemical Constituent	Nominal K_d Value in Sand (mL/g)	Federal and State^{a,b} MCL (mg/L)	Units	WMA A-AX Fenceline				100 meters Downgradient from WMA A-AX			
				Maximum Concentration (mg/L)	Peak Year	Maximum Concentration (mg/L)	Peak Year	Maximum Concentratio n (mg/L)	Peak Year	Maximum Concentration (mg/L)	Peak Year
Al	1,500	—^{c}	mg/L	0	0	0	0	0	0	0	0
Cr	0	0.1^{d}	mg/L	1.16E-05	1,000	9.33E-03	1,980	1.14E-05	1,000	9.32E-03	1,980
F	0	4	mg/L	1.60E-10	1,000	8.09E-04	2,160	1.14E-10	1,000	5.78E-04	2,170
Fe	25	—	mg/L	0	0	0	0	0	0	0	0
Hg	52	0.002	mg/L	0	0	0	0	0	0	0	0
Mn	65	—	mg/L	0	0	0	0	0	0	0	0
Ni	3	—	mg/L	0	0	0	0	0	0	0	0
NO_2	0	4.5	mg/L	4.15E-08	1,000	1.94E-01	2,120	2.98E-08	1,000	1.38E-01	2,120
NO_3	0	45	mg/L	6.15E-08	1,000	2.76E-01	2,120	4.40E-08	1,000	1.97E-01	2,120
Pb	10	—	mg/L	0	0	0	0	0	0	0	0
Sr	10	—	mg/L	0	0	0	0	0	0	0	0
U_Total	1	0.03	mg/L	0	0	4.37E-10	10,000	0	0	4.32E-10	10,000

GoldSim$^{©}$ Elements:
\Input_Parameters\Uncertainty_Inputs\Sorption_Uncertainty\Kd_Sand_Uncert,
\Transport_Abstraction_Model\SZ_Fence_Conc\Chem_Conc_fenceline,
\Transport_Abstraction_Model\SZ_100m_Conc\Chem_Conc_100m.

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WMA = Waste Management Area

[a] *Washington Administrative Code* (WAC) 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."

[b] The value for lead was obtained for 2007 Model Toxics Control Act (*Revised Code of Washington* 70.105D, "Hazardous Waste Cleanup—Model Toxics Control Act") WAC 173-340-900, "Tables," Table 720-1 Method A Cleanup Levels for Groundwater.

[c] "—" indicates no limit.

[d] as total chromium.

Table 7-2. Maximum Groundwater Concentration for All Chemicals with Inventories Greater than Zero in AX Farm at 100 meters Downgradient from Waste Management Area A-AX over the 0- to 1,000-year and 1,000- to 10,000-year Post-Closure Time Frames.

Chemical Constituent	Nominal K_d Value in Sand (mL/g)	Federal and State[a,b] MCL (mg/L)	Units	WMA A-AX Fenceline				100 meters Downgradient from WMA A-AX			
				Maximum Concentration (mg/L)	Peak Year	Maximum Concentration (mg/L)	Peak Year	Maximum Concentration (mg/L)	Peak Year	Maximum Concentration (mg/L)	Peak Year
Al	1,500	—[c]	mg/L	0	0	0	0	0	0	0	0
Cr	0	0.1[d]	mg/L	3.41E-06	1,000	2.42E-03	1,950	3.38E-06	1,000	2.42E-03	1,950
F	0	4	mg/L	2.42E-12	1,000	7.35E-04	2,390	2.11E-12	1,000	3.15E-04	2,390
Fe	25	—	mg/L	0	0	0	0	0	0	0	0
Hg	52	0.002	mg/L	0	0	0	0	0	0	0	0
Mn	65	—	mg/L	0	0	0	0	0	0	0	0
Ni	3	—	mg/L	0	0	0	0	0	0	0	0
NO_2	0	4.5	mg/L	3.26E-10	1,000	8.34E-02	2,320	2.82E-10	1,000	3.58E-02	2,310
NO_3	0	45	mg/L	6.73E-10	1,000	1.92E-01	2,310	5.72E-10	1,000	8.24E-02	2,320
Pb	10	—	mg/L	0	0	0	0	0	0	0	0
Sr	10	—	mg/L	0	0	0	0	0	0	0	0
U_Total	0.6	0.03	mg/L	0	0	3.22E-11	10,000	0	0	3.20E-11	10,000

GoldSim© Elements:
\Input_Parameters\Uncertainty_Inputs\Sorption_Uncertainty\Kd_Sand_Uncert,
\Transport_Abstraction_Model\SZ_Fence_Conc\Chem_Conc_fenceline,
\Transport_Abstraction_Model\SZ_100m_Conc\Chem_Conc_100m
GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).
WMA = Waste Management Area

[a] *Washington Administrative Code* (WAC) 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."

[b] The value for lead was obtained for 2007 Model Toxics Control Act (*Revised Code of Washington* 70.105D, "Hazardous Waste Cleanup—Model Toxics Control Act") WAC 173-340-900, "Tables," Table 720-1 Method A Cleanup Levels for Groundwater.

[c] "—" indicates no limit.

[d] as total chromium.

Peak concentrations were calculated by summing the contaminant concentrations from all A Farm and AX Farm sources separately. The process model, upon which the GoldSim© system model is based, calculated the highest groundwater concentration by evaluating the average concentration in the aquifer within a series of nine aquifer segments oriented parallel to the WMA A-AX fenceline (RPP-CALC-63164, *WMA A-AX Performance Assessment Contaminant Fate and Transport Process Model to Evaluate Impacts to Groundwater*). Concentrations calculated in the nine aquifer segments are intended to be comparable to concentrations that would be measured by sampling a monitoring well at those locations. The POCs are aligned such that the centerline of the plume in groundwater resulting from all of the sources intersects the set of segments near their center. The peak concentration in the process model occurred in a POC at the centerline of A Farm sources, and this POC was used for the one-dimensional system model with the sum of all contributions from all sources in either A Farm or AX Farm providing the maximum concentration. Evaluation of the process model results (RPP-ENV-61497) indicates insignificant lateral dispersion in the vadose zone such that the plume from A Farm sources does not interact with the plume from AX Farm sources. Therefore, impacts on groundwater will be reported separately for A Farm and AX Farm.

The modeling results indicate that only chemicals with K_d values in sand equal to 0 mL/g from the grouted WMA A-AX tank residuals reach groundwater within the 0- to 1,000-year post-closure period (Table 7-1 and Table 7-2). The list includes chromium, fluoride, nitrate, and nitrite. The earliest peak concentration of any of these chemicals occurs approximately 1,980 years post-closure. Uranium is the only chemical with a K_d value greater than zero (0.6 mL/g) that appears in the groundwater during the simulation. Uranium concentrations appear late in the simulation and are still rising at the end of the simulation, indicating that the peak concentration has not been reached at 10,000 years post-closure.

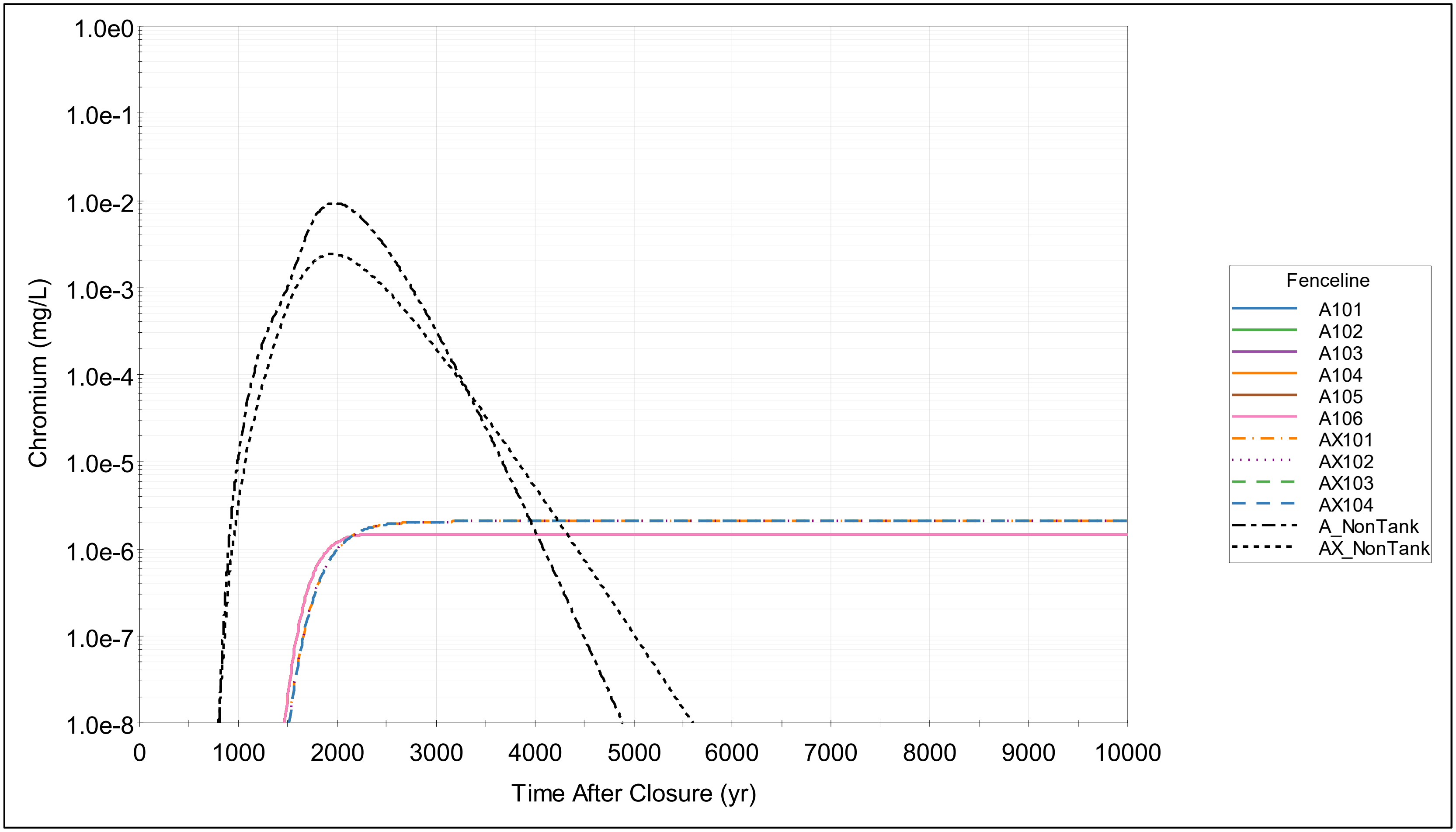
All contaminants reaching groundwater during the 1- to 1,000-year post-closure period are several orders of magnitude below their respective MCLs. During the 1,000- to 10,000-year post-closure period, chromium concentrations are a little over 9% of the MCL at A Farm both at the fenceline and 100 m downgradient. Chromium concentrations from AX Farm are about 2.4% of the MCL both at the fenceline and 100 m downgradient. At A farm in the 1,000- to 10,000 year post-closure period, nitrite concentrations are 4.3% of the MCL at the fenceline and almost a little over 3% of the MCL at 100 m downgradient. AX Farm nitrite concentrations in the same period are almost 2% of the MCL at the fenceline and 0.8% at 100 m downgradient. Nitrate concentrations from both farms are less than 1% of the MCL at both POCs, fluoride remains more than a factor of 5,000 or more below its MCL during the simulation, and uranium concentrations are several orders of magnitude below its MCL at the end of the simulation.

The following sections show detailed breakthrough curves for chemicals reaching groundwater within the model time frame broken down by each source’s contribution to the overall concentration.

7.1.2.1 Chromium. The breakthrough curves of chromium (Figure 7-5 and Figure 7-6) show two different behaviors related to the difference of source term release between tank sources and non-tank sources. For non-tank sources, the advective release results in a rapid increase of concentration, peaking at about 2,000 years post-closure followed by a rapid decrease in concentration as the contamination leaves the system. The time series from tank sources exhibit a rapid increase later in the simulation, followed by a flattening of the concentration curve that extends to the end of the simulation. The later arrival of chromium from tank sources reflects the diffusive release from tanks. The flattening of the concentration time series for chromium from tank sources indicates the dissolved concentration limit of 2,000 µg/L (RPP-RPT-60885) within the waste form has been reached. The chromium concentration does not decrease before the end of the simulation because the chromium in the tank sources is not depleted in that time frame. Note that all of the tanks within A Farm and all of the tanks within AX Farm produce the same chromium groundwater concentration, despite having different inventories. This is because the inventories in all the tanks are sufficiently high enough to maintain the maximum concentration within the waste form, resulting in the same release rate and groundwater concentration for each tank within a farm. The difference in the chromium concentrations from A Farm tank sources and from AX Farm tank sources is because AX Farm tank sources have a thicker base mat, which means a longer diffusive length, resulting in a lower release rate and subsequent chromium concentration in groundwater. The K_d of chromium, when adjusted for gravel content, is 0 mL/g in all hydrostratigraphic units (HSUs), which means transport of chromium through the vadose zone is not impeded by HSU thickness nor grain size (e.g., silt, sand or gravel). The overall vadose zone thickness in A Farm is 4 m greater than in AX Farm, which causes a slightly later arrival time at the POC. The impact from the slight difference in vadose zone thicknesses is overcome by the impacts arising from the differences in source term releases between the two farms. Therefore, POC concentrations are more dependent on Darcy Flux and source term release than on vadose zone properties.

7.1.2.2 Fluoride, Nitrate and Nitrite. Fluoride (Figure 7-7 and Figure 7-8), nitrate (Figure 7-9 and Figure 7-10) and nitrite (Figure 7-11 and Figure 7-12) all have K_d values of 0 mL/g, and are not constrained by dissolved concentration limits as chromium is. Therefore, these three chemicals exhibit very similar breakthrough curves, the magnitudes of which are a reflection of the initial chemical inventory in the residual waste. Nitrite and nitrate from non-tank sources appear in the breakthrough curves starting at approximately 1,000 years post-closure, while fluoride from non-tank sources does not appear in the breakthrough curves. This is because the inventories for nitrate and nitrite are two to three orders of magnitude greater than that of fluoride in the non-tank sources. The slower decline in groundwater concentrations after the peak from tanks A-104 and A-105 is caused by the lower release rates from these tanks due to their larger residual waste volume, leading to a slower depletion of inventory than in the other tanks. Chemicals from AX Farm tanks also have concentrations that decline more slowly after the peak than those from tanks A-101, 241-A-102 (A-102), 241-A-103 (A-103) and 241-A-106. This too is because chemicals in the AX Farm tank wastes deplete more slowly. In this case, it is because of a thicker base mat in the AX Farm tanks, which increases the diffusion length and lowers the release rate into the vadose zone. Nitrate and nitrite, like chromium, have K_d values of 0 mL/g in all HSUs and therefore behave like chromium in the vadose zone. Fluoride, however, has K_d values of 0 mL/g in all HSUs except the Cold Creek Silt unit (CCUz), where it has a K_d value of 0.05 mL/g. Given that the CCUz is 3.13 m thick in A Farm and 4.01 m thick in AX Farm (RPP-ENV-61497), fluoride would be impeded more in the vadose zone under AX Farm and would have a slightly later arrival time at the fenceline than at A Farm.

Figure 7-5. Groundwater Concentration of Chromium from All Sources in Waste Management Area A-AX at the Waste Management Area A-AX Fenceline Through the End of the Post-Closure Period.



GoldSim© Element: \Transport_Abstraction_Model\Cr_Fence_Conc_by_Source_Chrt.

Figure 7-6. Groundwater Concentration of Chromium from All Sources in Waste Management Area A-AX at 100 meters Downgradient from Waste Management Area A-AX Through the End of the Post-Closure Period.

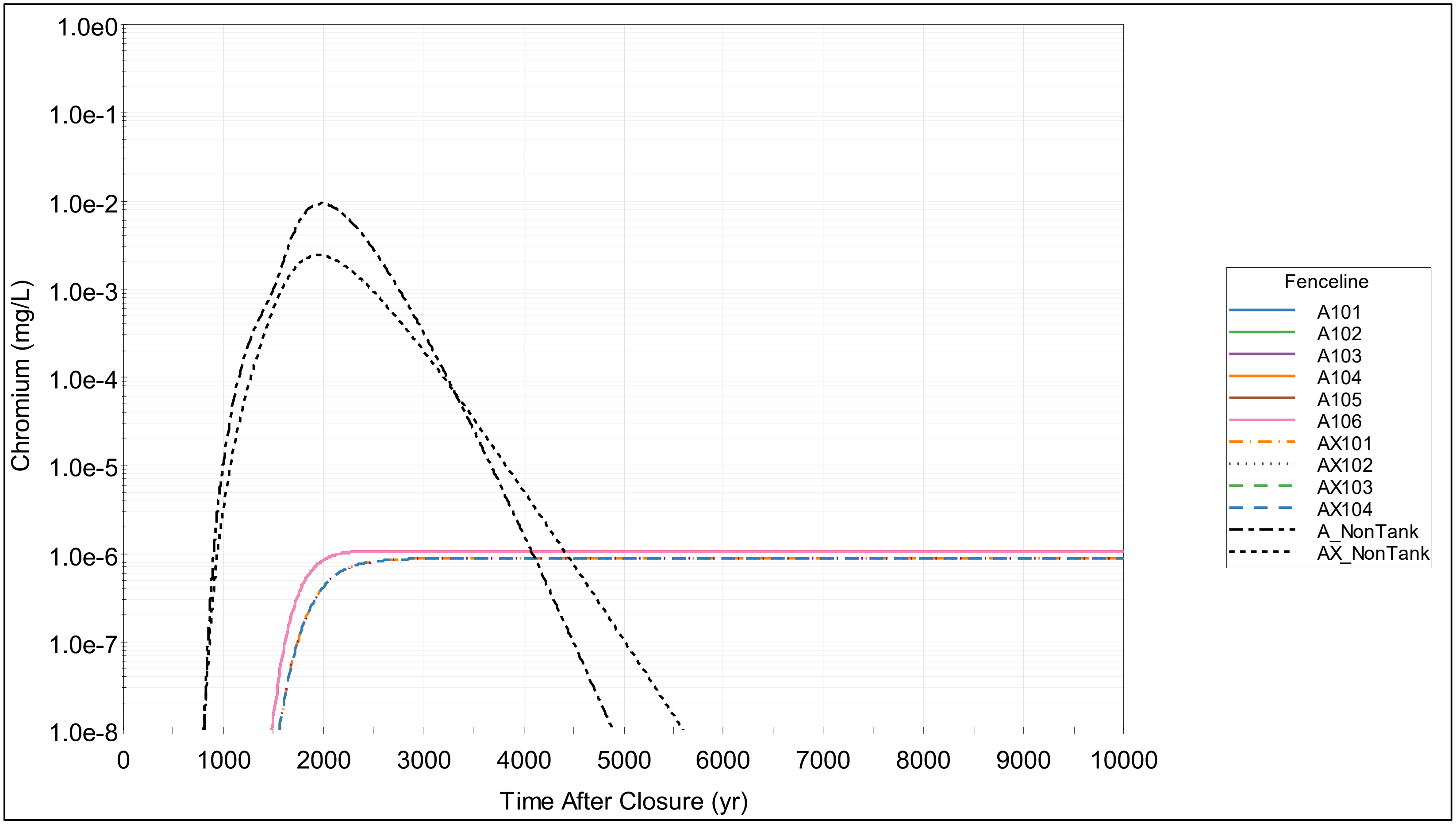


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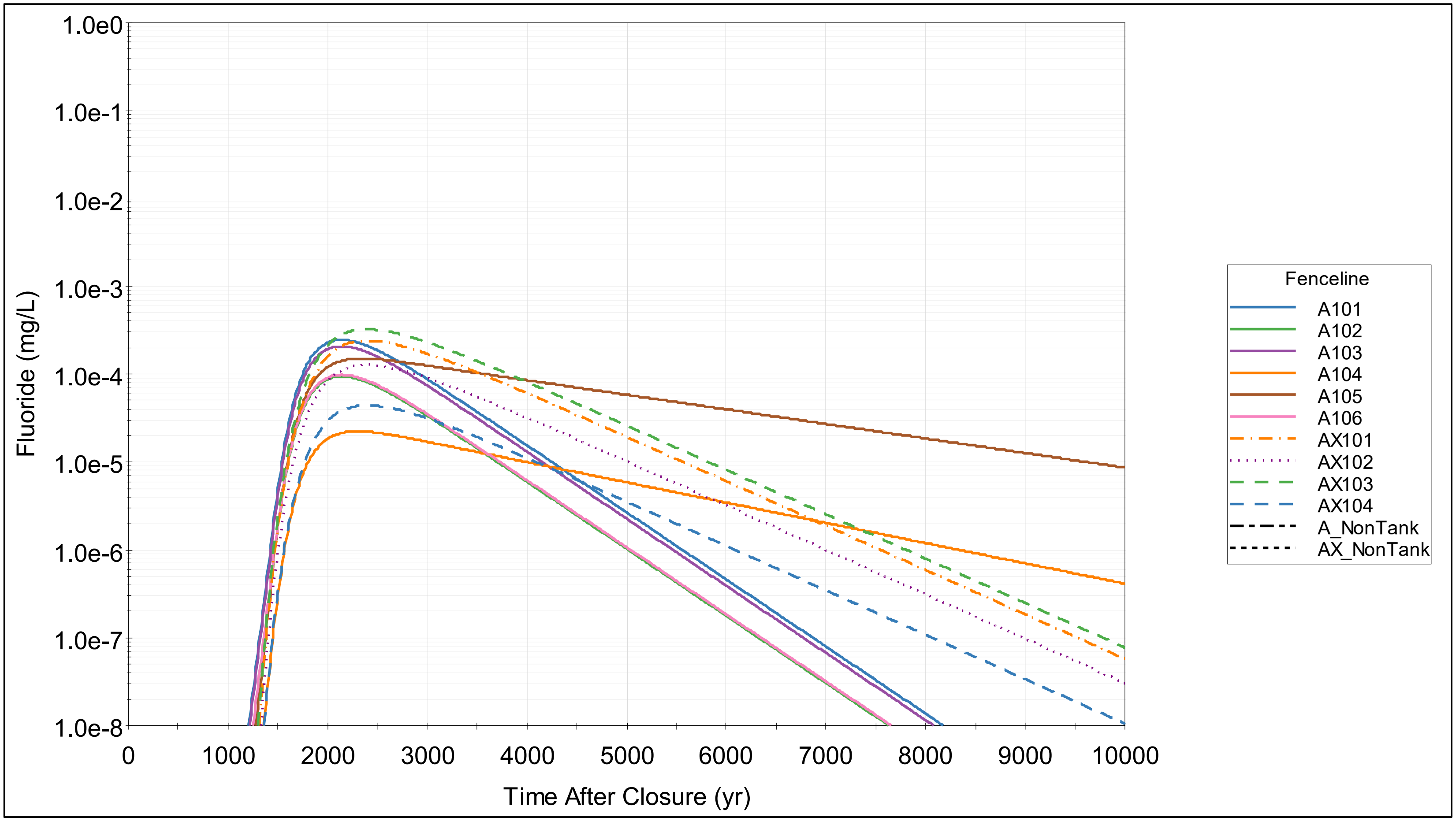
Figure 7-7. Groundwater Concentration of Fluoride from All Sources in Waste Management Area A-AX at the Waste Management Area A-AX Fenceline Through the End of the Post-Closure Period.



GoldSim© Element: \Transport_Abstraction_Model\F_Fence_Conc_by_Source_Chrt.

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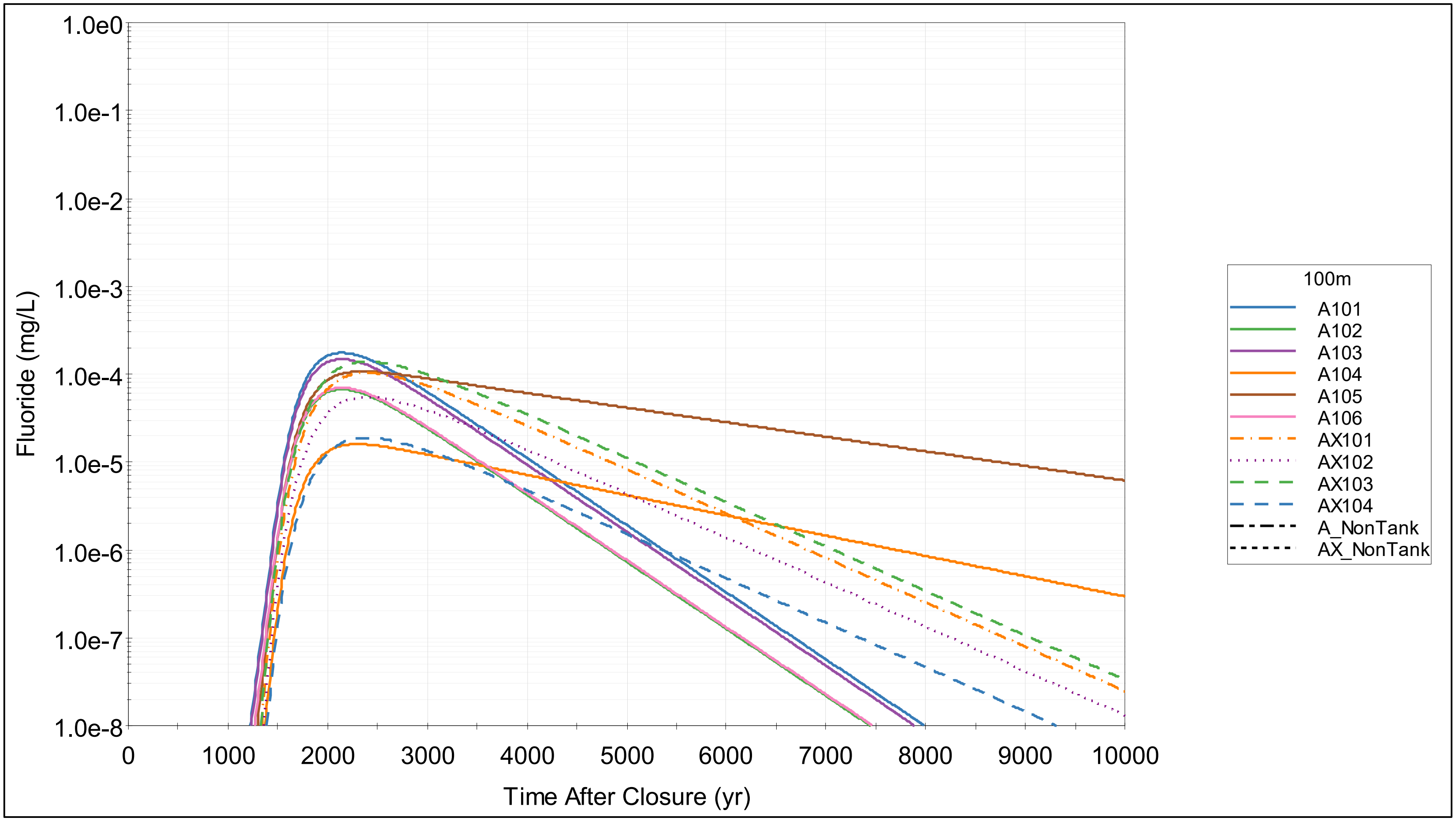
Figure 7-8. Groundwater Concentration of Fluoride from All Sources in Waste Management Area A-AX at 100 meters Downgradient from Waste Management Area A-AX Through the End of the Post-Closure Period.



GoldSim© Element: \Transport_Abstraction_Model\F_100m_Conc_by_Source_Chrt.

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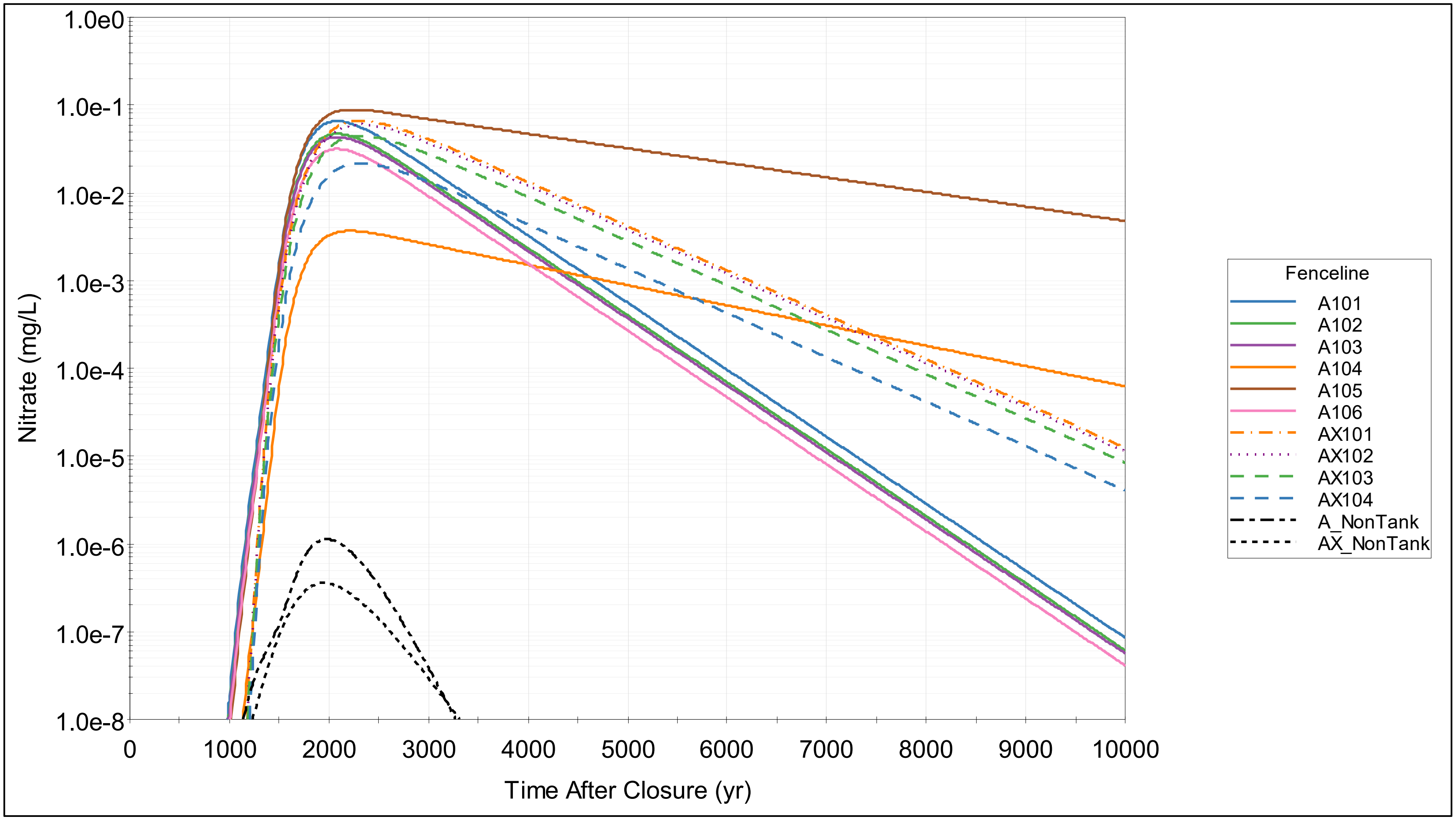
Figure 7-9. Groundwater Concentration of Nitrate from All Sources in Waste Management Area A-AX at the Waste Management Area A-AX Fenceline Through the End of the Post-Closure Period.



GoldSim© Element: \Transport_Abstraction_Model\NO3_Fence_Conc_by_Source_Chrt.

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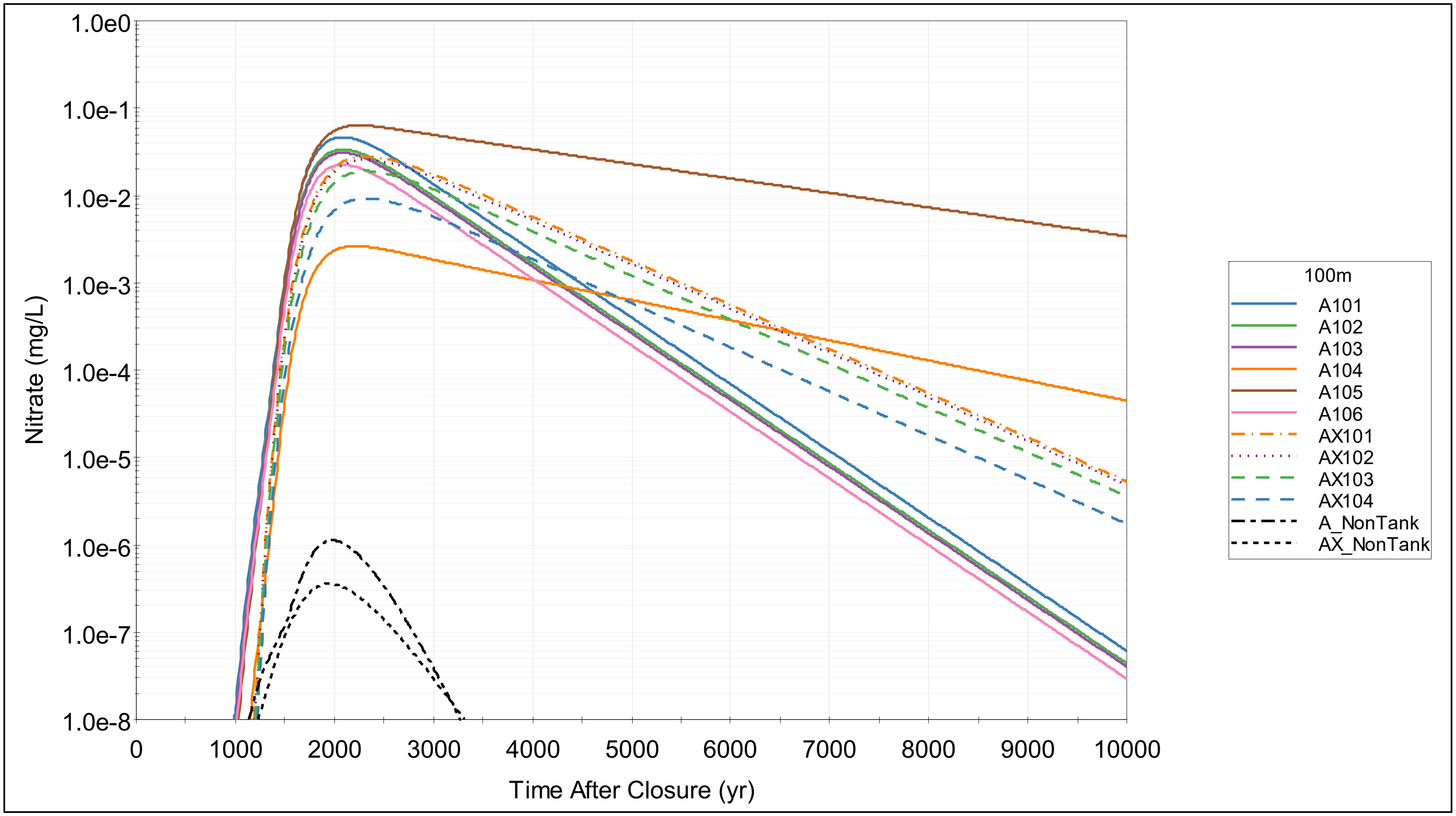
Figure 7-10. Groundwater Concentration of Nitrate from All Sources in Waste Management Area A-AX at 100 meters Downgradient from Waste Management Area A-AX Through the End of the Post-Closure Period.



GoldSim© Element: \Transport_Abstraction_Model\NO3_100m_Conc_by_Source_Chrt.

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Figure 7-11. Groundwater Concentration of Nitrite from All Sources in Waste Management Area A-AX at 100 meters Downgradient from Waste Management Area A-AX Through the End of the Post-Closure Period.

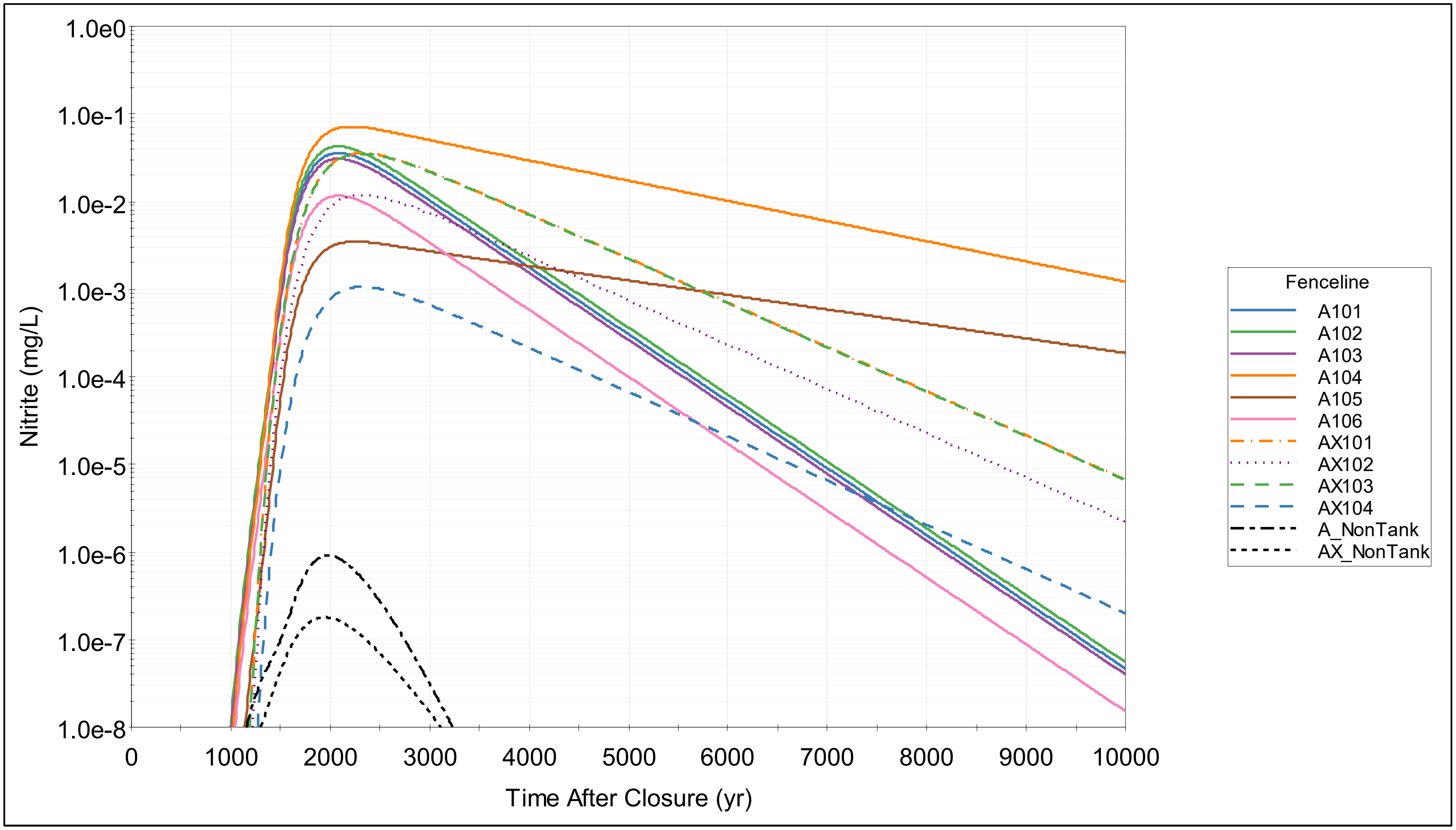

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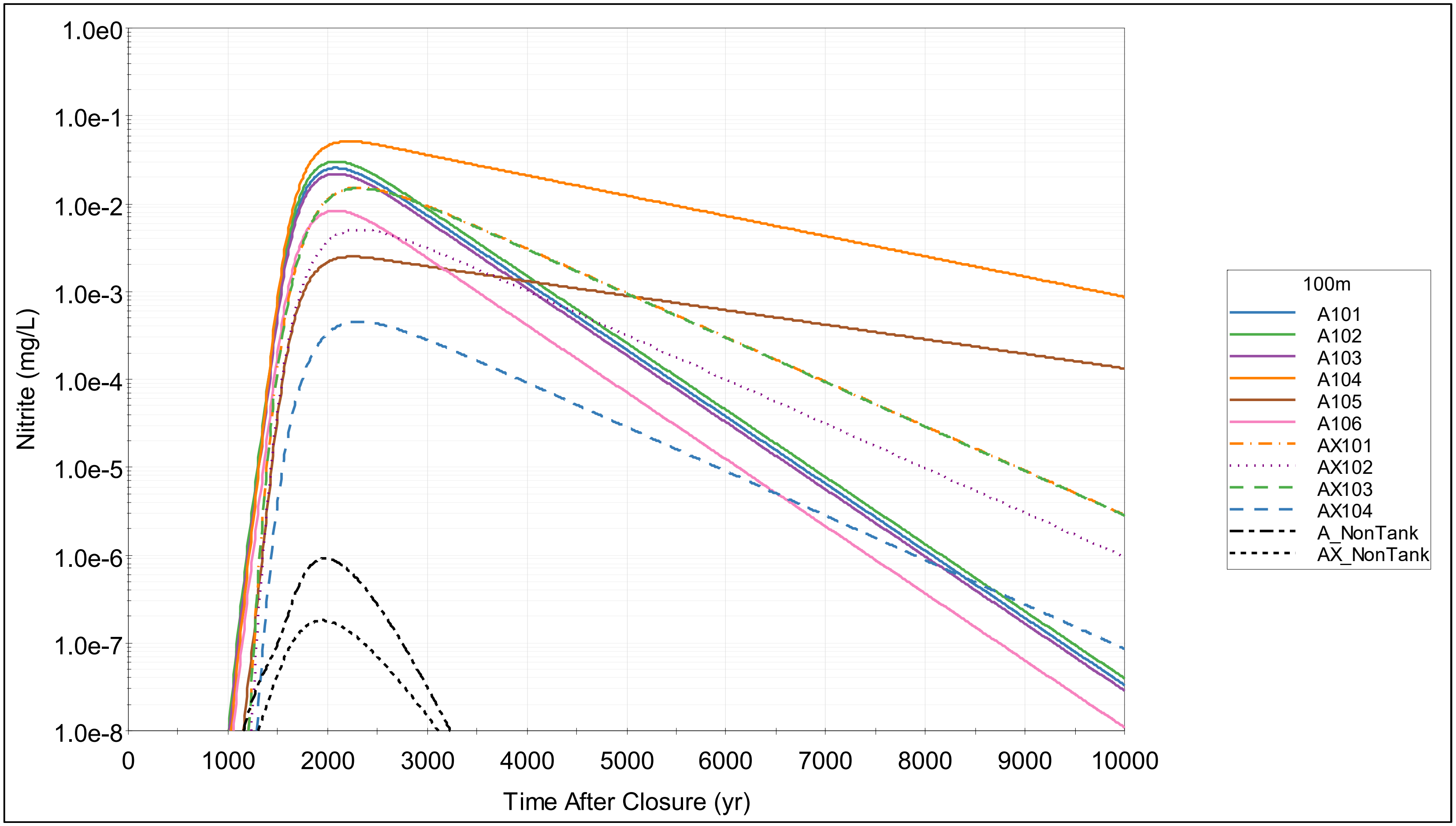
Figure 7-12. Groundwater Concentration of Nitrite from All Sources in Waste Management Area A-AX at 100 meters Downgradient from Waste Management Area A-AX Through the End of the Post-Closure Period.



GoldSim© Element: \Transport_Abstraction_Model\NO2_100m_Conc_by_Source_Chrt.

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7.1.2.3 Uranium. The breakthrough curves for uranium (Figure 7-13 and Figure 7-14), which has a K_d of 0.6 mL/g (for < 2 mm size material), show the effects of retardation on contaminant transport through the vadose zone. The total uranium concentration from any source first reaches 1×10^{-19} mg/L at approximately 6,700 years after closure at both the fenceline and 100 m downgradient. It reaches a maximum concentration of 4.37×10^{-10} mg/L at the A Farm fenceline and 4.32×10^{-10} mg/L at 100 m downgradient from A Farm by the end of the simulation. The source responsible for the highest A Farm concentration is the A Farm non-tank source. The AX Farm non-tank source is responsible for the highest AX Farm concentration. These results are not surprising because the non-tank sources both have an advection-dominated release with a combined uranium inventory of approximately 720 kg.

Uranium has a K_d in both sand and silt of 0.6 mL/g; however, when corrected for the gravel content of each HSU, the K_d is changed slightly as shown in Table 7-3.

Table 7-3. K_d Values for Uranium Adjusted for Hydrostratigraphic Unit Gravel Content.

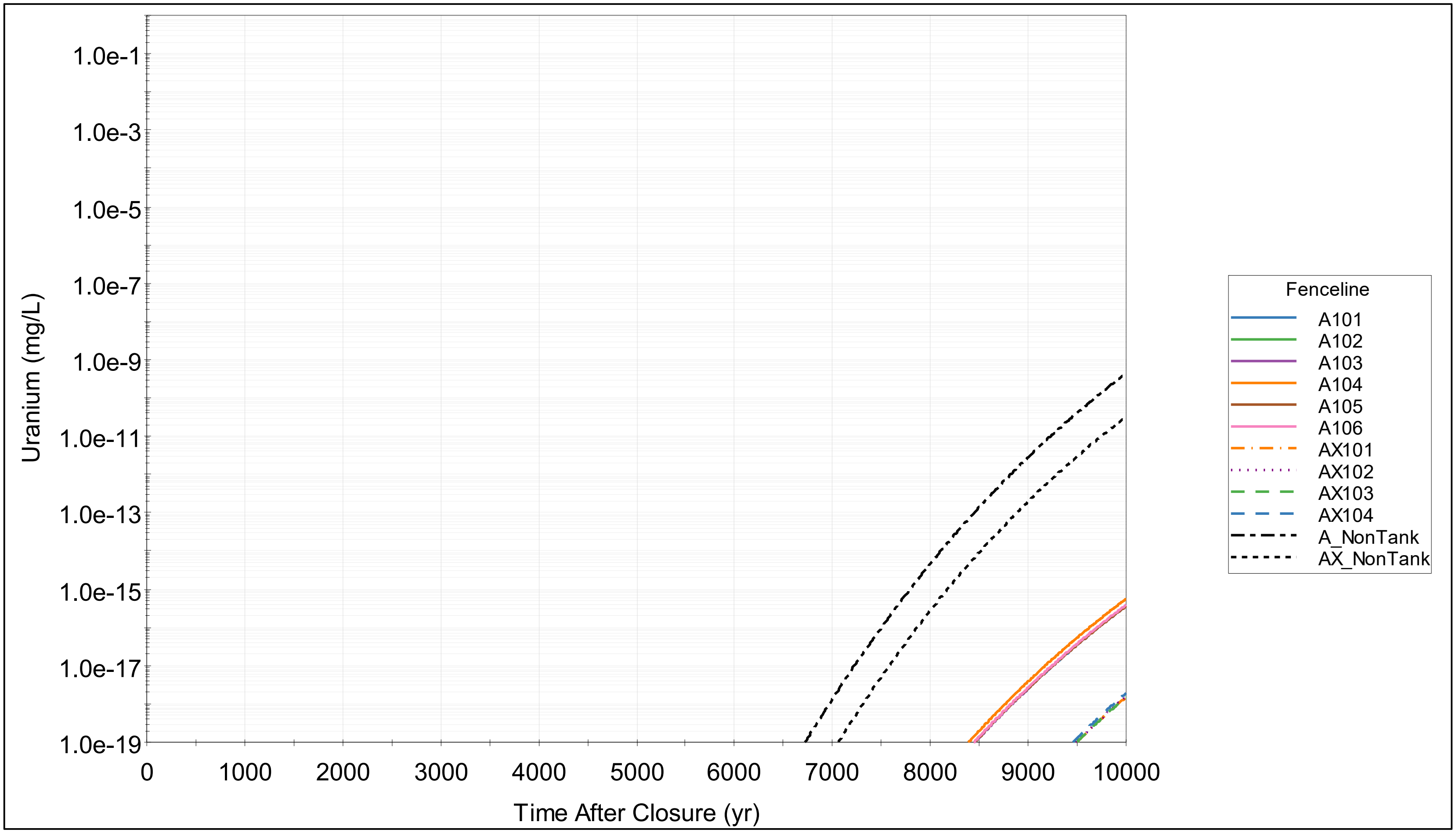
Hydrostratigraphic Unit	K_d (mL/g)
Hanford formation unit 1 (H1)	0.57
Hanford formation unit 2 (H2)	0.57
Hanford formation unit 3 (H3)	0.20
Cold Creek gravel (CCUg)	0.20
Cold Creek silt (CCUz)	0.60

Additionally, the HSU thicknesses are different between A Farm and AX Farm. The combination of K_d difference and HSU thickness results in a different rate of transport through the subsurface in A Farm than in AX Farm. If residual inventory and release rate were held the same between the A Farm non-tank source and the AX Farm non-tank source, uranium from the AX Farm non-tank source would reach groundwater first. However, since the A Farm non-tank source has over ten times more uranium inventory than the AX Farm non-tank source, its release rate is higher, which results in A Farm non-tank source uranium reaching the groundwater first, and having a substantially greater groundwater concentration over time than that from the AX Farm non-tank source.

7.1.3 Summary of U.S. Environmental Protection Agency Tap Water Cancer Risks

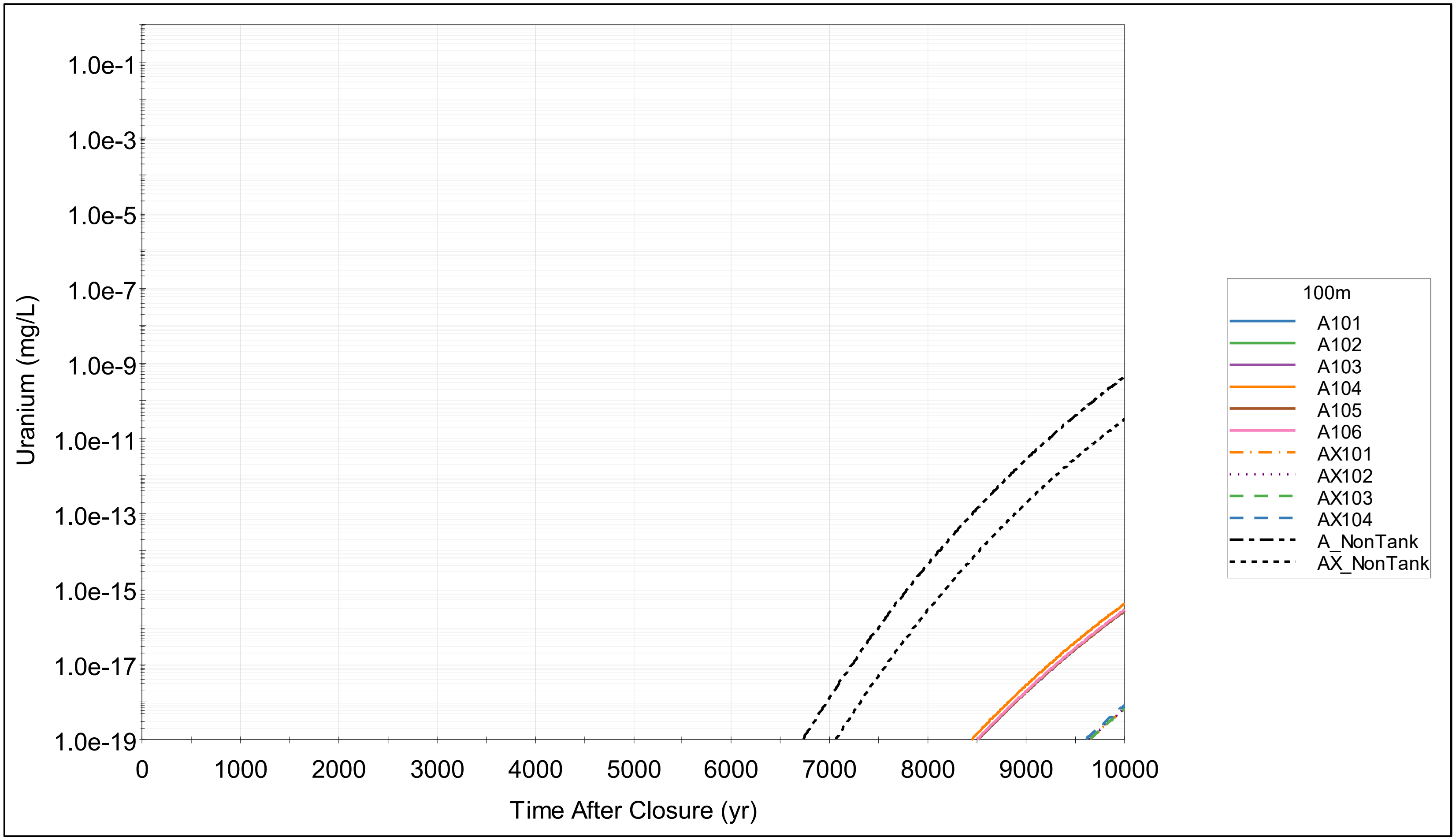
Peak cumulative chemical cancer risk is not discussed because carcinogenic chemicals were not observed in groundwater during the entire period of analysis.

Figure 7-13. Groundwater Concentration of Uranium from All Sources in Waste Management Area A-AX at the Waste Management Area A-AX Fenceline Through the End of the Post-Closure Period.



GoldSim© Element: \Transport_Abstraction_Model\U_Fence_Conc_by_Source_Chrt.

Figure 7-14. Groundwater Concentration of Uranium from All Sources at Waste Management Area A-AX at 100 meters Downgradient from Waste Management Area A-AX Through the End of the Post-Closure Period.



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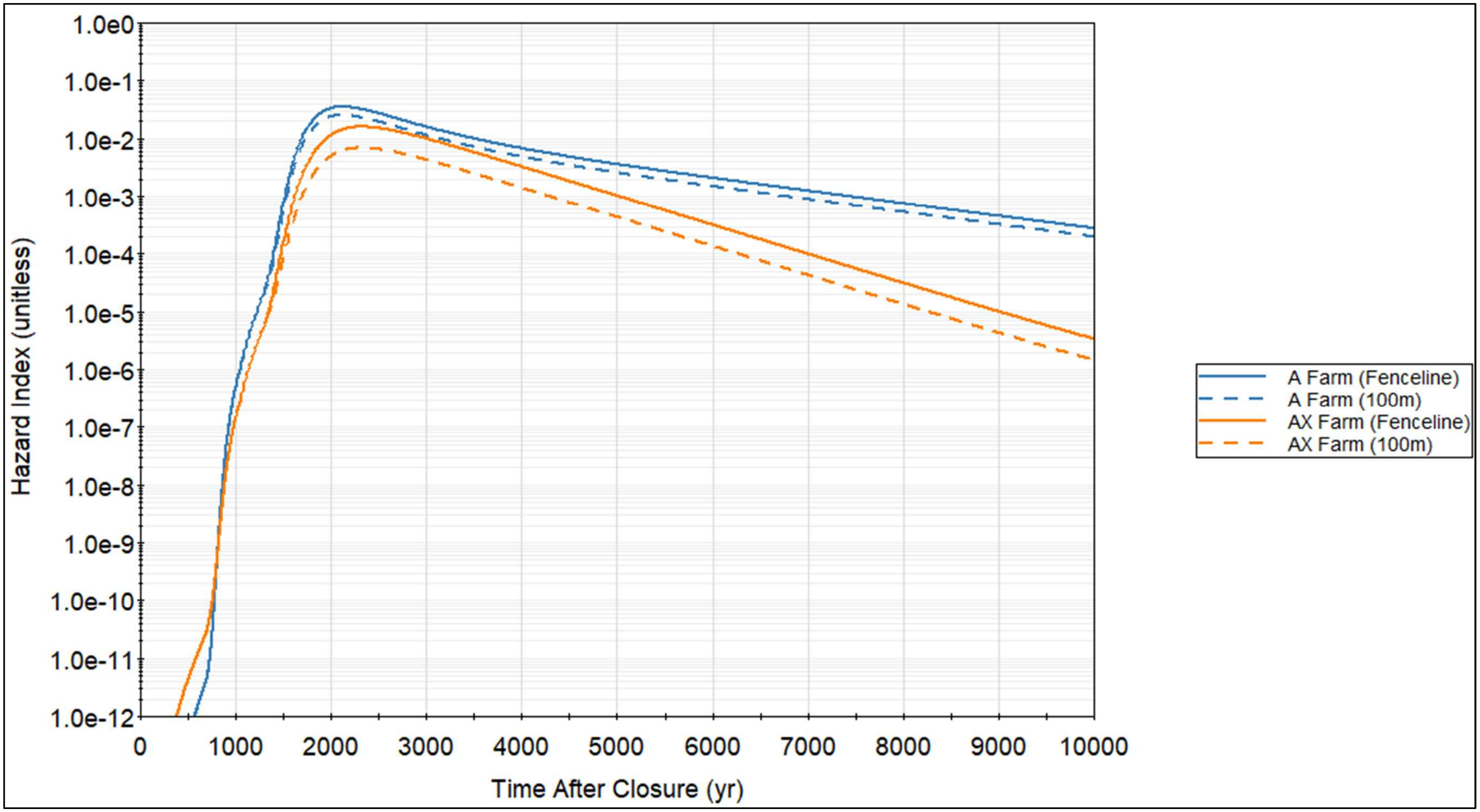
The chromium inventory evaluated in this analysis is total chromium. Trivalent chromium [Cr(III)] is not identified as a carcinogen, but hexavalent chromium is. The amount of hexavalent chromium in the residual waste and the amount that impacts groundwater are both highly uncertain. Analysis of samples of solid phases from tank 241-C-106 indicates that the majority of chromium is in the reduced trivalent [Cr(III)] oxidation state (RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*). Analyses of tank farm sediments indicate that interaction with ferrous [Fe(II)] minerals in the soil react with tank fluids reducing hexavalent chromium to trivalent chromium that then coprecipitates as a ferric-chromic hydroxide (PNNL-17154, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*). Given this research, it is highly unlikely that a high percentage of the total chromium inventory impacting groundwater is in the hexavalent form. However, if all of the total chromium is assumed to be hexavalent chromium (a highly improbable and bounding situation), the peak chemical risk would be from A Farm (8.65×10^{-5} at both the fenceline and 100 m downgradient, occurring 1,980 years after closure) and is driven entirely by hexavalent chromium from A Farm non-tank sources. The peak risk from AX Farm would be 2.25×10^{-5} at the fenceline and 2.24×10^{-5} at 100 m downgradient, both occurring 1,950 years after closure and driven entirely by hexavalent chromium from AX Farm non-tank sources.

7.1.4 Summary of U.S. Environmental Protection Agency Tap Water Non-Cancer Hazards

Cumulative non-cancer hazards from A Farm and AX Farm at their respective WMA A-AX fenceline and 100-m POCs are presented in Figure 7-15. The peak chemical non-cancer HI at the WMA fenceline, summed over all sources in A Farm, is about 0.035, occurring at 2,120 years post-closure. At 100 m downgradient from the facility it is 0.025, occurring at 2,120 years post-closure. The HIs at these locations are both less than the target HI of 1. The peak cumulative HI for AX Farm at the WMA fenceline is 1.6×10^{-2}, occurring at 2,320 years post-closure. At 100 m downgradient from the facility the peak from AX Farm is 6.9×10^{-3}, occurring 2,310 years post-closure. In most of the first 1,000 years of the simulation AX Farm has the highest non-cancer HI, but by 1,000 years after closure, A Farm has the highest HI which continues throughout the rest of the simulation.

As shown in Table 7-4, at the end of the 0- to 1,000-year post-closure period, the source with the highest HI at the WMA A-AX fenceline is the A Farm non-tank source (5.15×10^{-7}) followed closely by the AX Farm non-tank source (1.52×10^{-7}) and tank 241-A-102 (2.14×10^{-9}). At 100 m downgradient, the top contributing sources are the same: the A Farm non-tank source (5.09×10^{-7}) followed closely by the AX Farm non-tank source (1.51×10^{-7}) and tank 241-A-102 (1.52×10^{-9}). Non-tank source release is advection-driven, which accounts for its earlier arrival time than the diffusion-driven tank contaminant releases.

Figure 7-15. Comparison of 241-A Tank Farm and 241-AX Tank Farm Hazard Indices at the Waste Management Area A-AX Fenceline, and 100 meters Downgradient Over Time.



GoldSim© Element: \Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\Farm_Contributions_To_HI.

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Table 7-4. Summary of Peak Hazard Indices at Waste Management Area A-AX and Time of Occurrence for All Sources.

Source	**WMA A-AX Fenceline**				**100 meters Downgradient from WMA A-AX**			
	0 to 1,000 years Post-Closure Time Frame		**1,000 to 10,000 years Post-Closure Time Frame**		**0 to 1,000 years Post-Closure Time Frame**		**1,000 to 10,000 years Post-Closure Time Frame**	
	Peak Hazard Index	**Approximate Time of Peak (years)**	**Peak Hazard Index**	**Approximate Time of Peak (years)**	**Peak Hazard Index**	**Approximate Time of Peak (years)**	**Peak Hazard Index**	**Approximate Time of Peak (years)**
Tank 241-A-101	1.88E-09	1,000	6.61E-03	2,080	1.33E-09	1,000	4.72E-03	2,090
Tank 241-A-102	2.14E-09	1,000	7.49E-03	2,080	1.52E-09	1,000	5.35E-03	2,080
Tank 241-A-103	1.60E-09	1,000	5.61E-03	2,080	1.14E-09	1,000	4.01E-03	2,080
Tank 241-A-104	9.46E-10	1,000	1.20E-02	2,220	6.69E-10	1,000	8.59E-03	2,220
Tank 241-A-105	9.03E-11	1,000	1.33E-03	2,260	6.41E-11	1,000	9.52E-04	2,260
Tank 241-A-106	6.41E-10	1,000	2.25E-03	2,090	4.55E-10	1,000	1.61E-03	2,090
A Non-Tank	5.15E-07	1,000	4.15E-04	1,980	5.09E-07	1,000	4.15E-04	1,980
Cumulative A Farm HI	5.22E-07	1,000	3.53E-02	2,120	5.14E-07	1,000	2.53E-02	2,120
Tank 241-AX-101	5.75E-12	1,000	6.60E-03	2,320	2.46E-12	1,000	2.83E-03	2,320
Tank 241-AX-102	2.17E-12	1,000	2.49E-03	2,320	9.26E-13	1,000	1.07E-03	2,320
Tank 241-AX-103	5.60E-12	1,000	6.43E-03	2,320	2.38E-12	1,000	2.76E-03	2,320
Tank 241-AX-104	3.15E-13	1,000	3.66E-04	2,320	1.34E-13	1,000	1.57E-04	2,320
AX Non-Tank	1.52E-07	1,000	1.08E-04	1,950	1.51E-07	1,000	1.08E-04	1,950
Cumulative AX Farm HI	1.52E-07	1,000	1.60E-02	2,320	1.51E-07	1,000	6.88E-03	2,310

GoldSim© Elements: \Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\NonRad_HI_Peak_Time_by_Source
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations\A_Total_HI
\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations\AX_Total_HI.

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HI = Hazard Index

WMA = Waste Management Area

During the 1,000- to 10,000-year post-closure period, the contaminants from the closed tanks peak and the non-tank source contamination leaves the system. At the WMA fenceline, the source with the highest HI during this period is tank A-104 (1.20×10^{-2}) followed by tank A-102 (7.49×10^{-3}) and tank A-101 (6.61×10^{-3}), which together account for almost 75% of the overall HI in A Farm during this period (Table 7-4). At 100 m downgradient, the order of top contributors is the same: tank A-104 (8.59×10^{-3}) followed by tank A-102 (5.35×10^{-3}) and tank A-101 (4.72×10^{-3}). The sources with the highest HI at the WMA fenceline in AX Farm are tank 241-AX-101 (6.60×10^{-3}) and tank 241-AX-103 (6.43×10^{-3}), which together account for about 81% of the overall HI in AX Farm. At 100 m downgradient, the order of top contributors is the same: tank 241-AX-101 (2.83×10^{-3}) and tank 241-AX-103 (2.76×10^{-3}). Figure 7-16 shows the contribution of each source in A Farm over time at the WMA fenceline, and Figure 7-17 shows the same at the 100-m downgradient POC. Figure 7-18 shows the contribution of each source in AX Farm over time at the WMA fenceline, and Figure 7-19 shows the same at the 100-m downgradient POC.

Of the 18 chemicals modeled, only 5 have a non-zero HQ at any time in the 10,000-year time frame. These 5 chemicals are also the only ones of the group modeled with K_d values less than 1 mL/g. Chemicals with non-zero hazards are listed with their peak HQs during the 0- to 1,000-year and 1,000- to 10,000-year periods and compared to the peak HI during the same periods in Table 7-5 (fenceline) and Table 7-6 (100 m) for A Farm and Table 7-7 (fenceline) and Table 7-8 (100 m) for AX Farm.

For both A Farm and AX Farm at the end of the 0- to 1,000-year time period, the key contributing chemicals, at both the fenceline and 100 m downgradient, are chromium (98% or greater contribution), and nitrite (about 1% contribution in A Farm and 0.04% [fenceline] and 0.03% contribution [100 m] in AX Farm). The highest contributor from A Farm in the 1,000- to 10,000-year time period is nitrite (3.23×10^{-2} at the fenceline, 2.31×10^{-2} at 100 m), followed by nitrate (1.95×10^{-3} at the fenceline, 1.39×10^{-3} at 100 m) and fluoride (6.75×10^{-4} at the fenceline, 4.82×10^{-4} at 100 m). The total HI from A Farm in this time period is 3.53×10^{-2} (2,120 years post-closure) at the fenceline and 2.53×10^{-2} (2,120 years after closure) at 100 m downgradient. In AX Farm, for the same time period, the highest contributors are nitrite (1.39×10^{-2} at the fenceline, 5.97×10^{-3} at 100 m), nitrate (1.36×10^{-3} at the fenceline, 5.81×10^{-4} at 100 m) and fluoride (6.14×10^{-4} at the fenceline, 2.63×10^{-4} at 100 m). The total HI from AX Farm in this time period is 1.60×10^{-2} (2,320 years post-closure) at the fenceline and 6.88×10^{-3} (2,310 years after closure) at 100 m downgradient.

Hazard quotients over time for all chemicals providing non-zero hazard in A Farm during the model time frame are shown in Figure 7-20 and Figure 7-21. Figure 7-22 and Figure 7-23 show HQs over time for all chemicals providing non-zero hazard in AX Farm.

The HQ time series for chemicals with K_ds of 0 mL/g (fluoride, nitrite and nitrate) in both A Farm and AX Farm rapidly increase until the peak, followed by gradual declines for the remainder of the modeled time frame. Hazard quotients for these mobile contaminants are driven by releases from tanks, as the inventories of these contaminants in non-tank sources are exceedingly small.

Figure 7-16. Hazard Index over Time for Each Contributing Source at 241-A Tank Farm at the Waste Management Area A-AX Fenceline Point of Calculation.

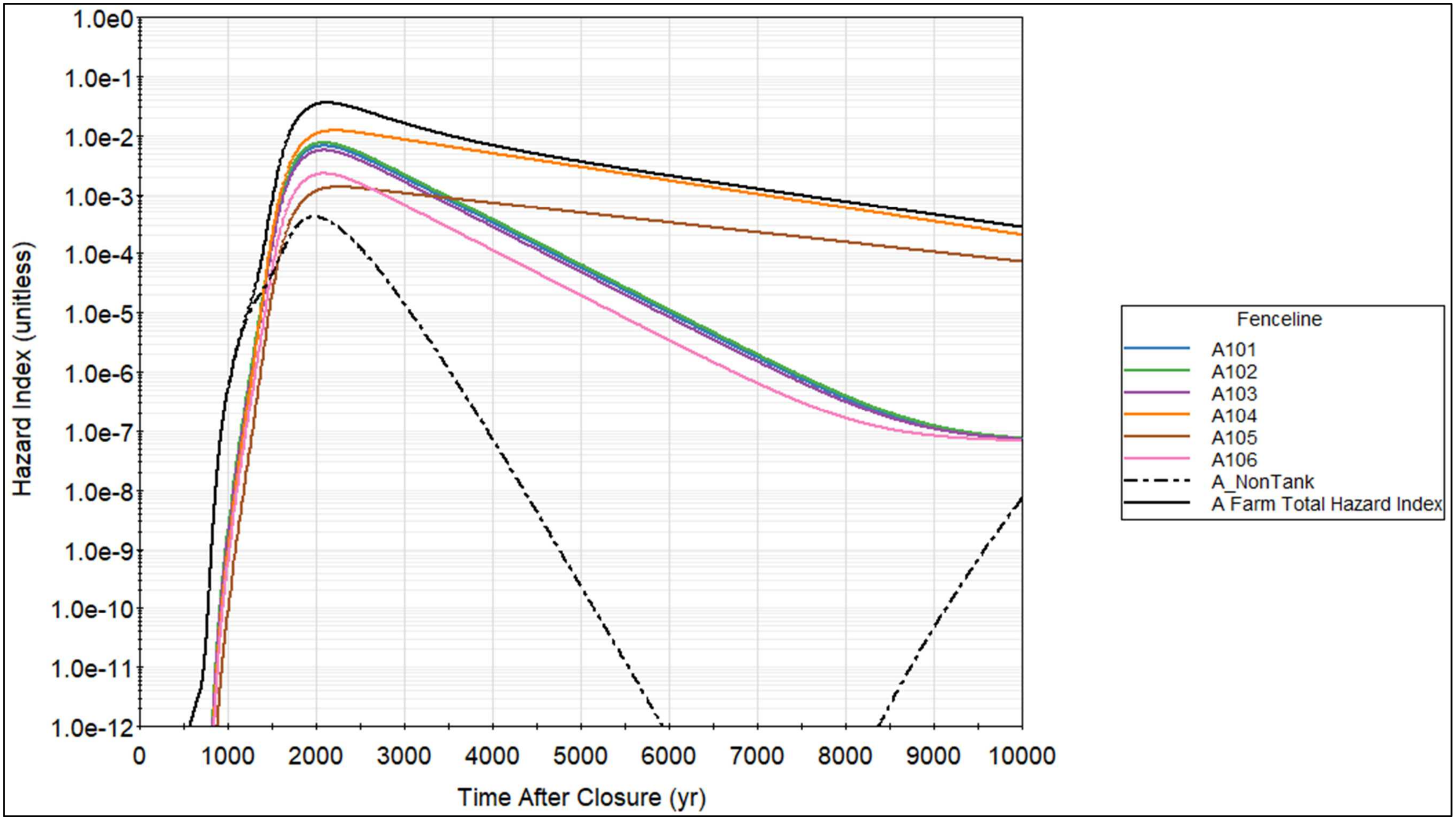

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Figure 7-17. Hazard Index over Time for Each Contributing Source at 241-A Tank Farm at the 100-meter Downgradient Point of Calculation.

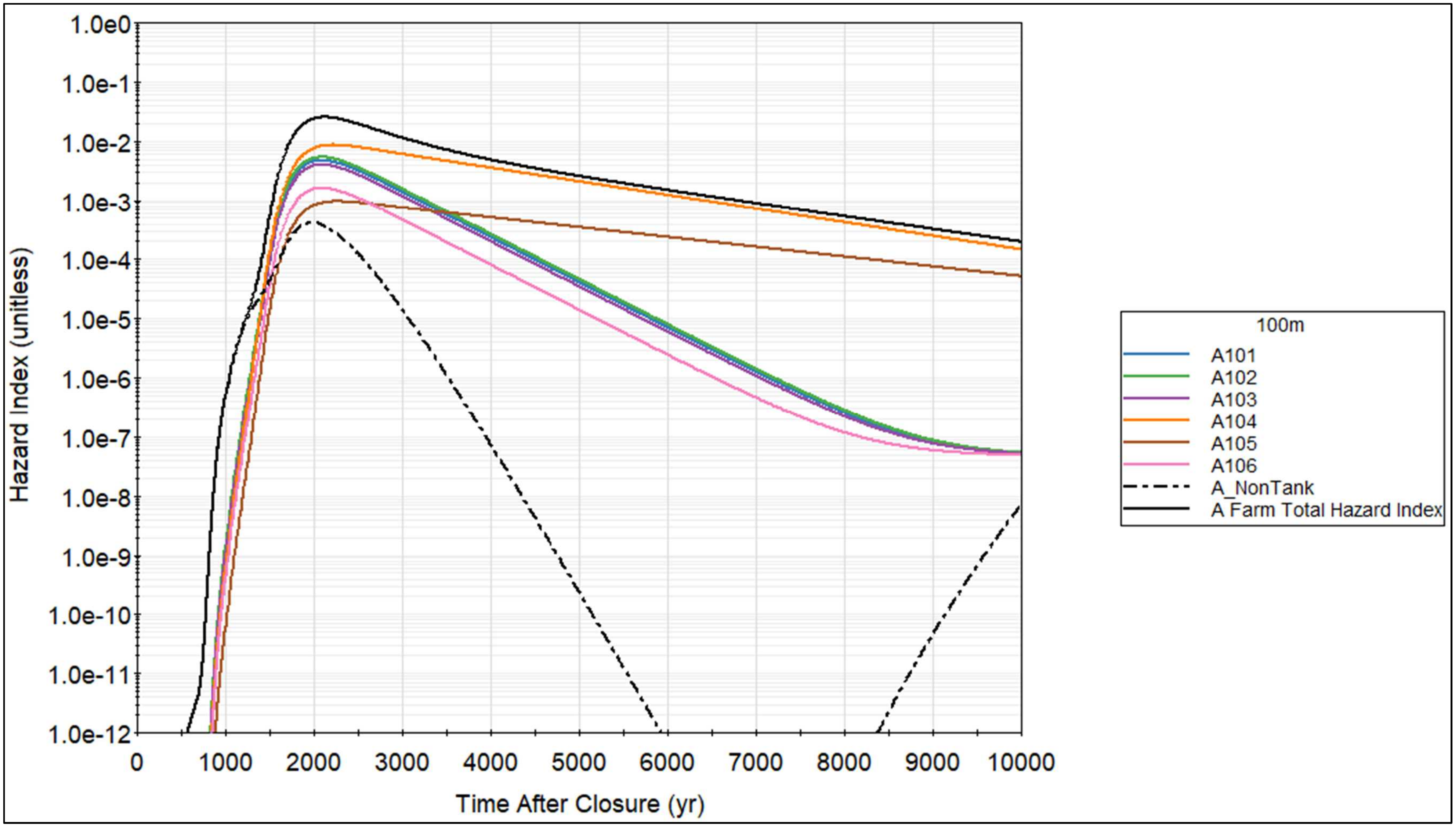

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Figure 7-18. Hazard Index over Time for Each Contributing Source at 241-AX Tank Farm at the Waste Management Area A-AX Fenceline Point of Calculation.

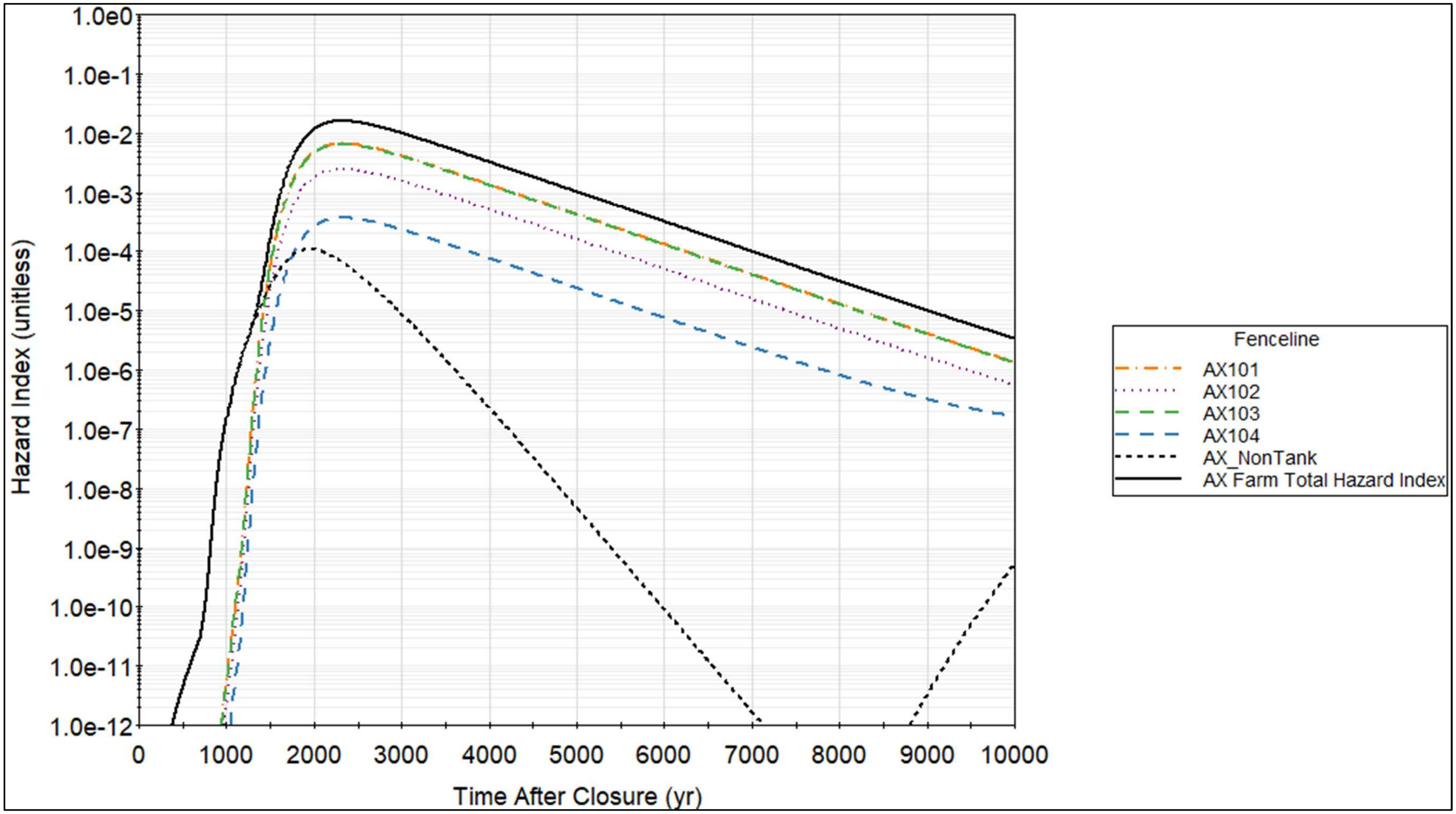

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Figure 7-19. Hazard Index over Time for Each Contributing Source at 241-AX Tank Farm at the 100-meter Downgradient Point of Calculation.

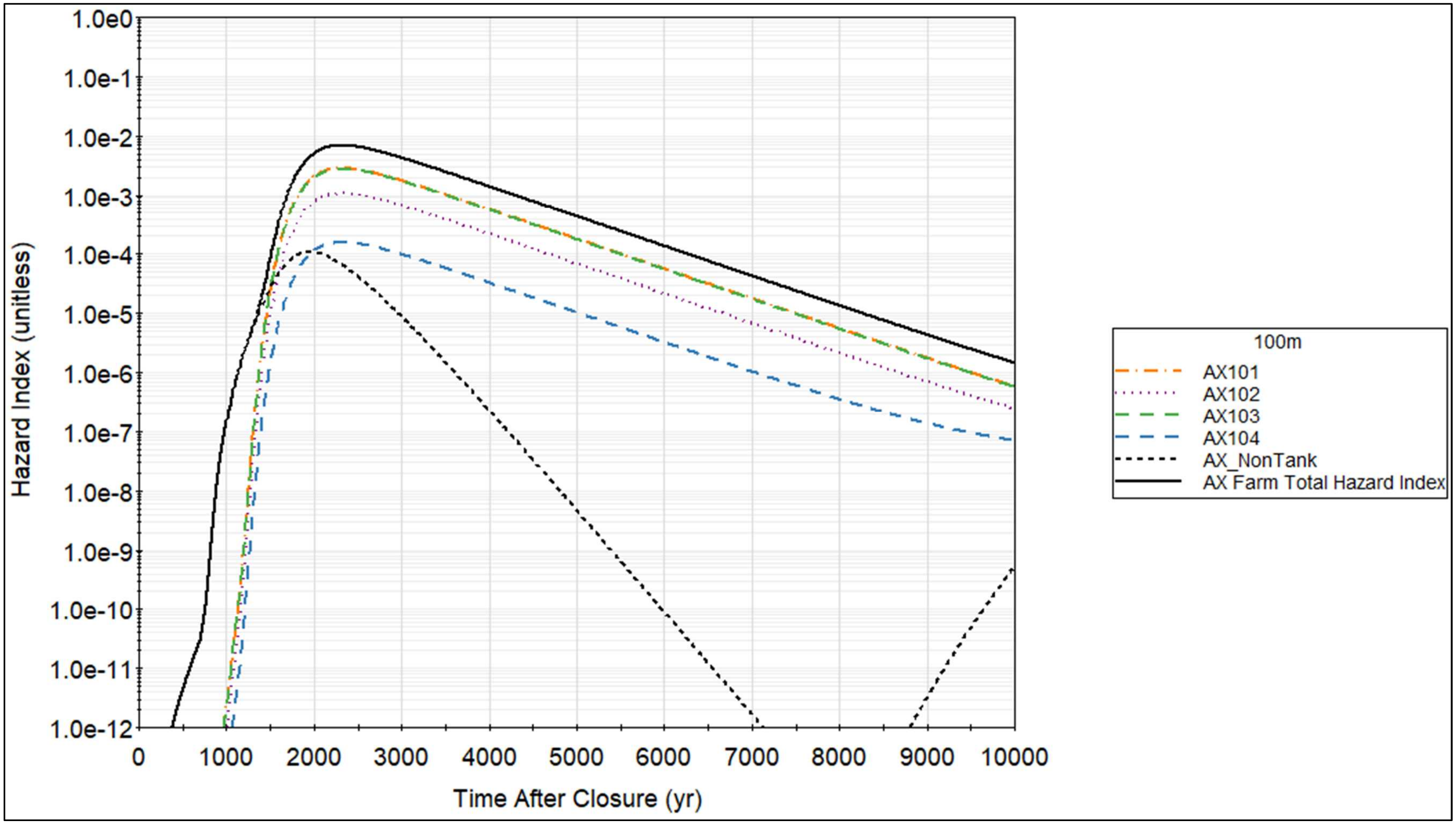

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Table 7-5. Summary of Peak Hazard Quotients from 241-A Tank Farm Sources at the 241-A Tank Farm Fenceline and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-year Period		1,000- to 10,000-year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	5.14E-07	1,000	4.15E-04	1,980
Fluoride	1.33E-10	1,000	6.75E-04	2,160
Nitrite	6.93E-09	1,000	3.23E-02	2,120
Nitrate	4.34E-10	1,000	1.95E-03	2,120
Uranium	0	0	7.30E-09	10,000
Hazard Index	5.22E-07	1,000	3.53E-02	2,120

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\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\A_NonRad_HQ_Peak_Time_by_Analy,
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Table 7-6. Summary of Peak Hazard Quotients from 241-A Tank Farm Sources at 100 meters Downgradient from Waste Management Area A-AX and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-year Period		1,000- to 10,000-year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	5.09E-07	1,000	4.15E-04	1,980
Fluoride	9.55E-11	1,000	4.82E-04	2,160
Nitrite	4.97E-09	1,000	2.31E-02	2,120
Nitrate	3.10E-10	1,000	1.39E-03	2,120
Uranium	0	0	7.22E-09	10,000
Hazard Index	5.14E-07	1,000	2.53E-02	2,120

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\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculations\A_Total_HI.

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Table 7-7. Summary of Peak Hazard Quotients from 241-AX Tank Farm Sources at the 241-AX Tank Farm Fenceline and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-year Period		1,000- to 10,000-year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	1.52E-07	1,000	1.08E-04	1,950
Fluoride	2.02E-12	1,000	6.14E-04	2,390
Nitrite	5.44E-11	1,000	1.39E-02	2,320
Nitrate	4.75E-12	1,000	1.36E-03	2,320
Uranium	0	0	5.38E-10	10,000
Hazard Index	1.52E-07	1,000	1.60E-02	2,320

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Table 7-8. Summary of Peak Hazard Quotients from 241-AX Tank Farm Sources at 100 meters Downgradient from Waste Management Area A-AX and Time of Occurrence for All Chemicals Giving Non-Zero Hazard.

Chemical	0- to 1,000-year Period		1,000- to 10,000-year Period	
	Peak Hazard Quotient	Approximate Time of Peak (years)	Peak Hazard Quotient	Approximate Time of Peak (years)
Chromium	1.51E-07	1,000	1.08E-04	1,950
Fluoride	1.76E-12	1,000	2.63E-04	2,390
Nitrite	4.71E-11	1,000	5.97E-03	2,320
Nitrate	4.04E-12	1,000	5.81E-04	2,320
Uranium	0	0	5.35E-10	10,000
Hazard Index	1.51E-07	1,000	6.88E-03	2,310

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Figure 7-20. Hazard Quotients Over Time at the Waste Management Area A-AX Fenceline Point of Calculation from All Chemicals at 241-A Tank Farm with Non-Zero Hazard.

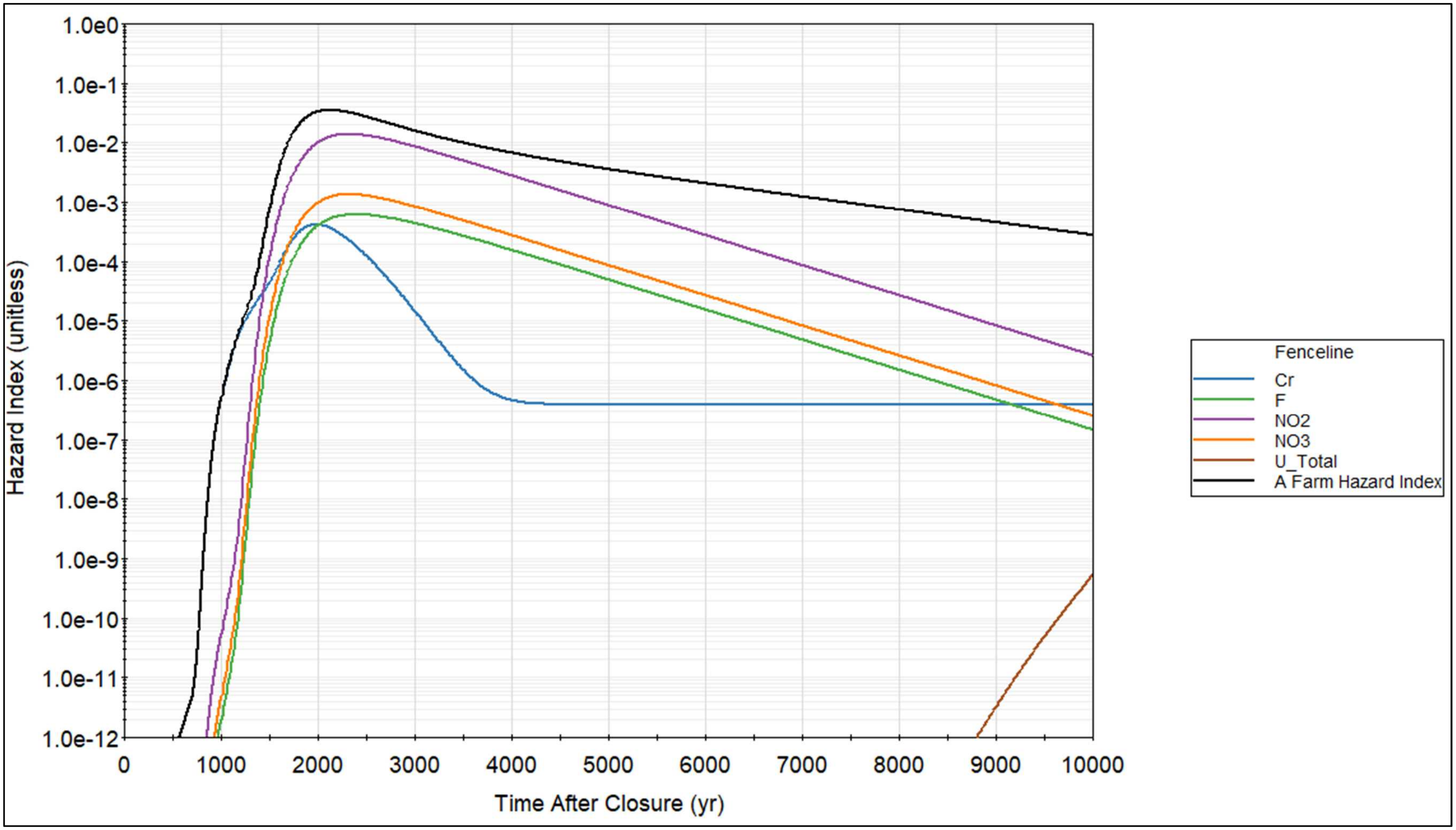

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Figure 7-21. Hazard Quotients Over Time at the 100-meter Downgradient Point of Calculation from All Chemicals at 241-A Tank Farm with Non-Zero Hazard.

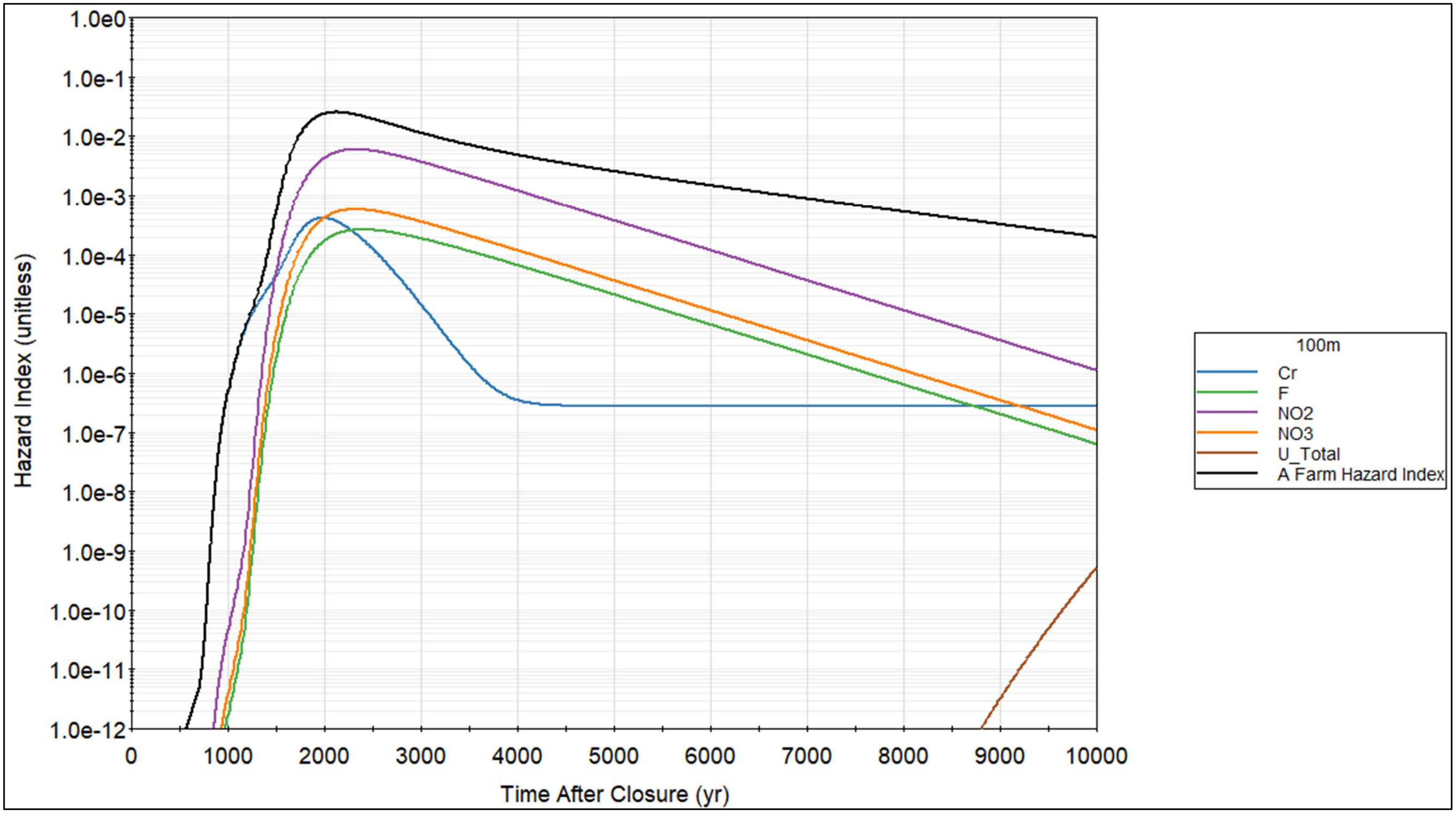

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Figure 7-22. Hazard Quotients Over Time at the Waste Management Area A-AX Fenceline Point of Calculation from All Chemicals at 241-AX Tank Farm with Non-Zero Hazard.

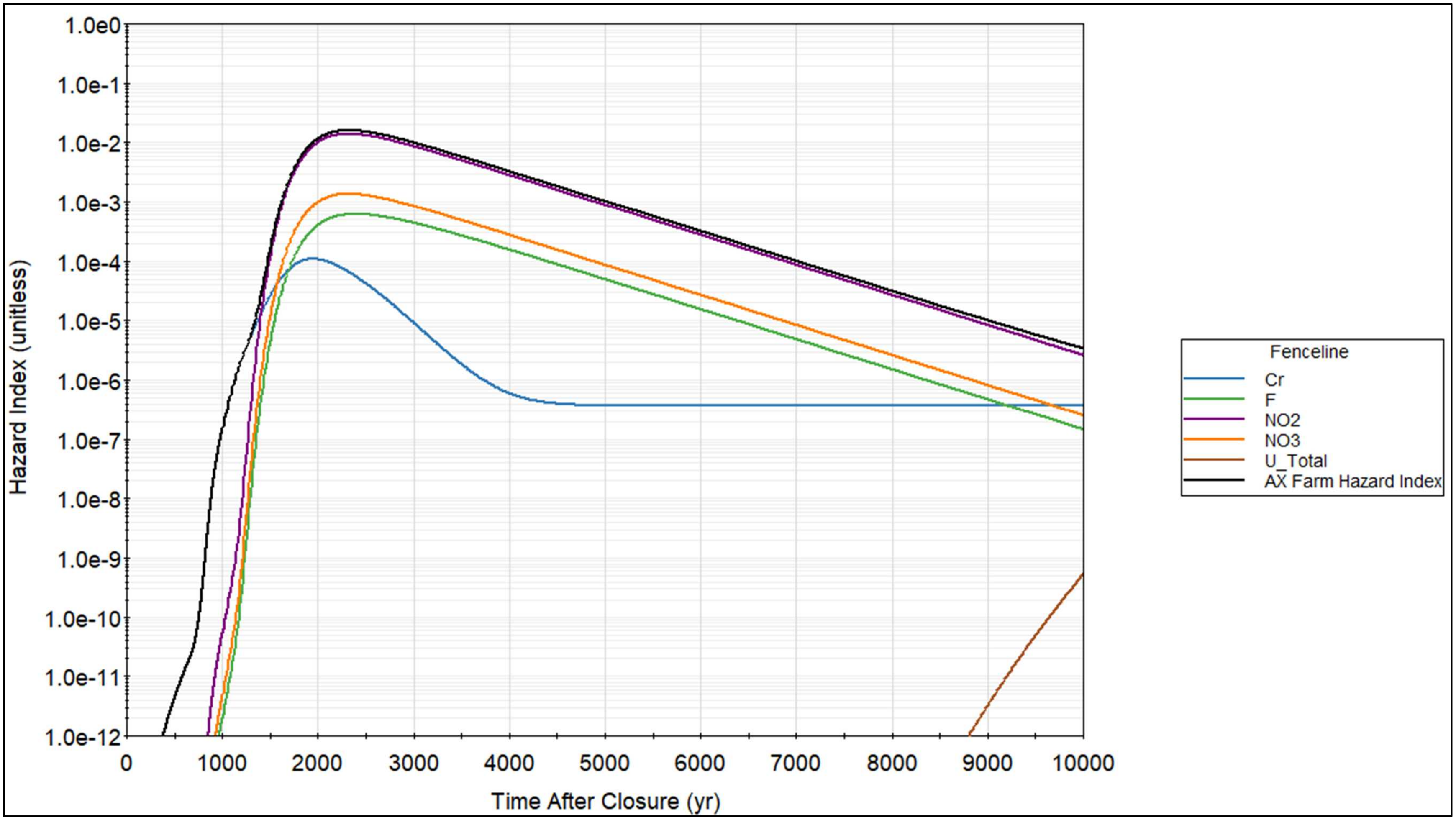

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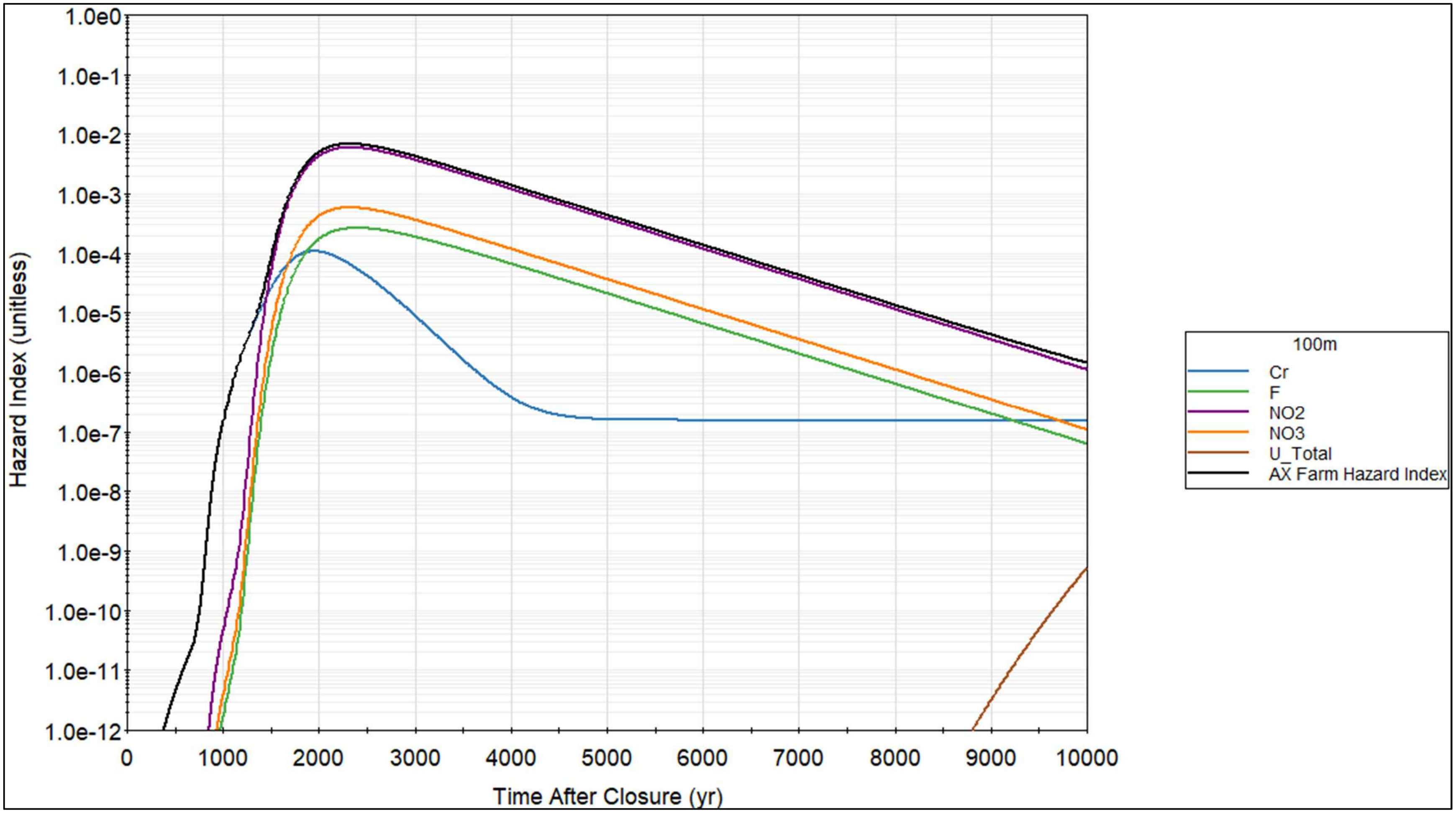
Figure 7-23. Hazard Quotients Over Time at the 100-meter Downgradient Point of Calculation from All Chemicals at 241-Tank AX Farm with Non-Zero Hazard.



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The flattening of the HQ time series for chromium (K_d = 0 mL/g) in both A Farm and AX Farm indicate the dissolved concentration limit of 2,000 µg/L has been reached, as discussed in Section 7.1.1. From about 500 to 4,000 years post-closure, the curve is dominated by the contribution of A Farm and AX Farm non-tank sources, which have the higher chromium inventory than the A Farm and AX Farm tank sources. The curve flattens out at about 4,000 years post-closure as the 2,000 µg/L dissolved concentration limit is reached and continues the same HQ to the end of the simulation because tank sources are not depleted during this period. Chromium from non-tank sources arrives earlier in the simulation because its release is advection-driven, while chromium from tank sources arrives later because it is released by diffusion.

As discussed in Section 7.1.3, the chromium inventory evaluated in this analysis is total chromium. If all of the total chromium inventory impacting groundwater were in hexavalent form (a highly improbable and bounding situation), the peak HQ would be from A Farm (2.1×10^{-1} occurring at 1,980 years after closure at both the fenceline and 100 m downgradient). This assumption would bring the peak HI to 2.4×10^{-1} at the fenceline and 2.3×10^{-1} at 100 m downgradient, both occurring at 1,990 years after closure. At AX Farm, the peak hexavalent chromium HQ would be 5.4×10^{-2} at 1,950 years after closure both at the fenceline and 100 m downgradient. These results would bring the peak HI to 6.5×10^{-2} at 2,000 years after closure at the fenceline and 5.9×10^{-2} at 1,970 years after closure at 100 m downgradient.

The HQ time series for uranium in both A Farm and AX Farm show the effect of moderate retardation on contaminant transport through the vadose zone. The HQ for uranium is greater than zero late in the simulated time frame, and the trend of the time series is increasing at the end of the simulation, indicating that it has yet to reach a peak. The residual waste in the non-tank sources is responsible for releases within 10,000 years, with all other sources negligible. This occurs because the release from the pipelines occurs by advection and is not retarded by sorption on cementitious material. By contrast, releases from the tanks and vault are influenced by sorption on the grout and are released by diffusion.

7.1.5 Sensitivity Analysis

Sensitivity analyses evaluate changes in calculated groundwater impacts that result from changing a broad set of input assumptions to represent alternative conceptual models or scenarios of future behavior. Primary sources of alternative modeling assumptions are natural system heterogeneities, long-term engineered surface barrier and tank shell performance, and human actions. Such assumptions can be categorized as scenario or model uncertainties, and as such are not readily amenable to the use of probabilistic methods (NCRP Report No. 152, "Decision analysis for low-level radioactive waste disposal safety assessments" [Kozak 1994]). Consequently, these analyses are run as deterministic sensitivity analyses, without assigning a likelihood of occurrence. The sensitivity analyses quantify the calculated groundwater concentration outcomes due to an underlying shift in the conceptual model. With respect to the defense-in-depth concept, the analyses quantify the impacts that alternative views of the natural and engineered barriers have on groundwater concentrations in the evaluation of total system performance.

The sensitivity analyses have been performed with nitrite, which has the highest impact on non-cancer hazards during the assessment timeframe. Generally, nitrite is expected to continue to have the highest impact on non-cancer hazards in the sensitivity analyses that do not significantly impact transport through the vadose zone. The exception is the sensitivity analyses that assume 100 mm/yr recharge instead of 3.5 mm/yr recharge. In this case moderately sorbing chemicals, e.g., total uranium, could arrive within 10,000 years and cause a greater impact to groundwater.

7.1.5.1 Surface Barrier Sensitivity Cases. The sensitivity cases described in this section investigate the impacts a surface barrier and surface vegetation have on groundwater concentrations. The list of infiltration sensitivity cases is presented in Table 7-9 and are detailed in RPP-CALC-63247.

Table 7-9. List of Surface Barrier Sensitivity Cases.

Case ID	Description	Recharge Rate
INF0 (Base Case)	Barrier degrades after first 500 years, and is replaced by native vegetation.	0.5 mm/yr from year 0 to 500, 3.5 mm/yr for remaining 9,500 years
INF1	Barrier remains intact for all 10,000 years.	0.5 mm/yr for 10,000 years
INF2	No barrier is constructed, and no vegetation grows for all 10,000 years.	100 mm/yr for 10,000 years
INF3	No barrier is constructed and native vegetation is reintroduced at time 0, and remains for all 10,000 years.	3.5 mm/yr for 10,000 years

Source: RPP-CALC-63247, *WMA A-AX Performance Assessment Sensitivity Analysis*, Table 4-1.

Figure 7-24 compares the total groundwater concentration for nitrite in the different surface barrier sensitivity cases at the compliance point of A Farm. The results for INF3 are very similar to that of the base case. INF3 concentration breaks through earlier during the compliance period than that of the base case. INF1's breakthrough and the peak concentration occur later after the compliance period. INF2's breakthrough curve is distinctly different from that of the base case, reflecting the behavior of contaminants from the pipelines in the high-recharge flow field.

The base case peak concentration of nitrite from A Farm is 0.14 mg/L at 2,120 years post-closure. The concentration in the INF3 sensitivity is similar, peaking at 0.12 mg/L at 1,920 years post-closure. INF2, with a high recharge rate throughout the simulation, peaks at 0.45 mg/L at 172 years post-closure. Conversely INF1, with a low recharge rate throughout the simulation, peaks at 0.05 mg/L at 7,130 years after closure.

Table 7-10 shows the peak nitrite concentrations from all sources at A Farm and AX Farm at the 100-m point of calculation for the surface barrier sensitivity cases and the base case.

Figure 7-24. Nitrite Groundwater Concentrations from All 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Surface Barrier Sensitivity Cases.

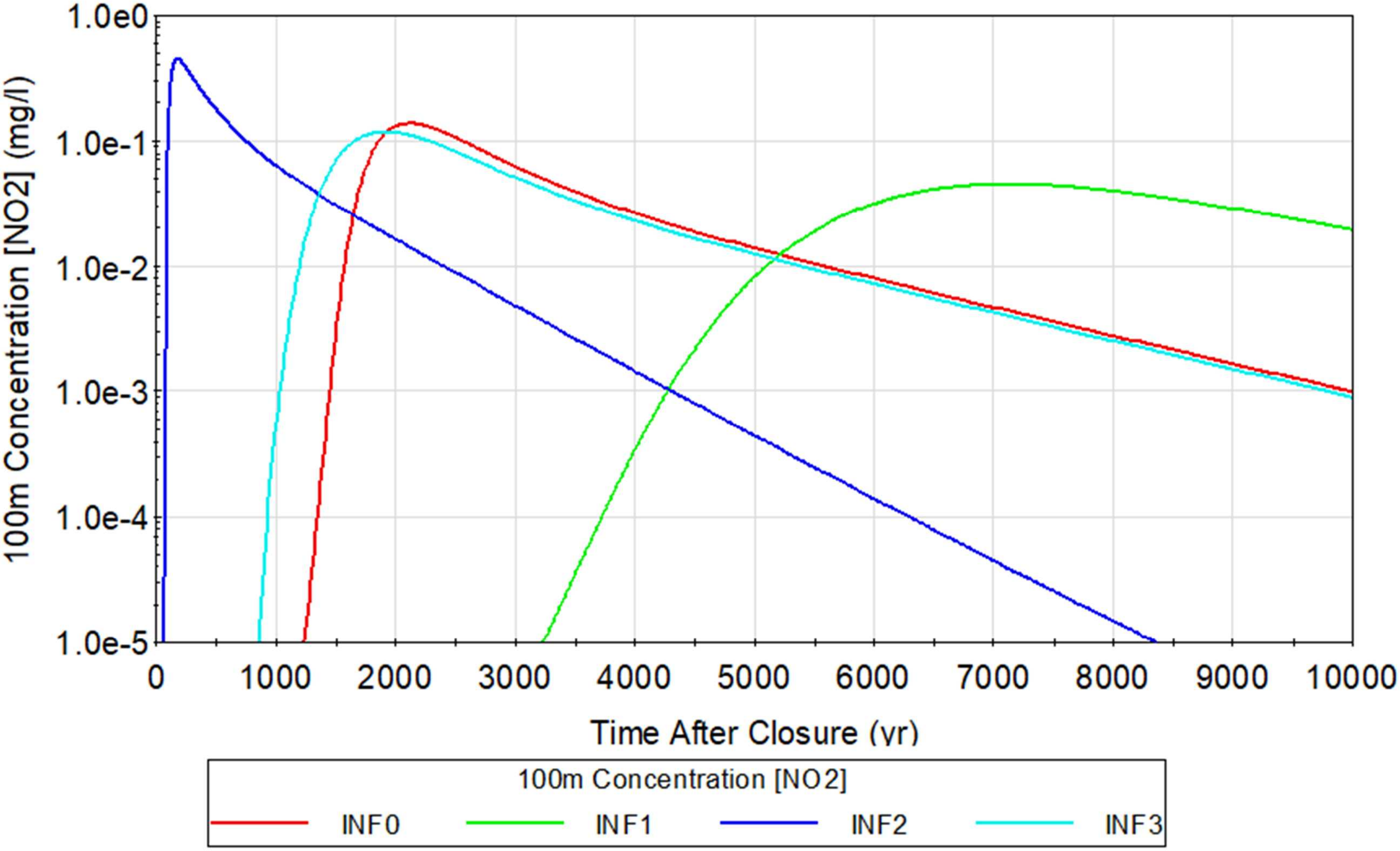

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Table 7-10. Peak Nitrite Concentration and Peak Arrival Times for Base Case (INF0), INF1, INF2 and INF3.

Farm Name	Case Name	Peak Concentration (mg/L)	Peak Time (years after closure)
241-A Tank Farm	Base Case (INF0)	0.1384	2,120
	INF1	0.0452	7,130
	INF2	0.4530	172
	INF3	0.1195	1,920
241-AX Tank Farm	Base Case (INF0)	0.0358	2,320
	INF1	0.0124	7,170
	INF2	0.1234	186
	INF3	0.0327	2,110

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Figure 7-25 through Figure 7-28 show the individual A Farm source contributions to nitrite groundwater concentrations at 100 m downgradient from WMA A-AX for each sensitivity case. In all cases, the magnitude of the peak groundwater concentrations from the tanks are proportional to their nitrite inventory, with tank A-104 having the highest peak, and the A Farm non-tank sources having the lowest. As explained in Section 7.1.2.2, the breakthrough curves for tanks A-104 and A-105 are different from the other A Farm tanks because of their larger residual waste volumes.

7.1.5.2 Inventory Sensitivity Cases. Inventory sensitivity cases were performed to evaluate upper bound inventories in the tanks and ancillary equipment. Sensitivity case INV1's upper bound residual waste volumes are based on current unretrieved BBI volumes for tanks and ancillary equipment. Sensitivity case INV2 is an evaluation of ancillary equipment residual estimates at post-retrieval estimated volumes, but using the average BBI composition of the tank waste instead of HTWOS composition in the base case. Residual volumes and inventory for tanks A-104 and A-105 remain the same for the base case and the two inventory sensitivity cases.

For tank sources, the base case calculation employed the inventories that are developed using BBI current tank waste concentrations and the residual waste volumes for the tank inventories.

Figure 7-25. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case INF0.

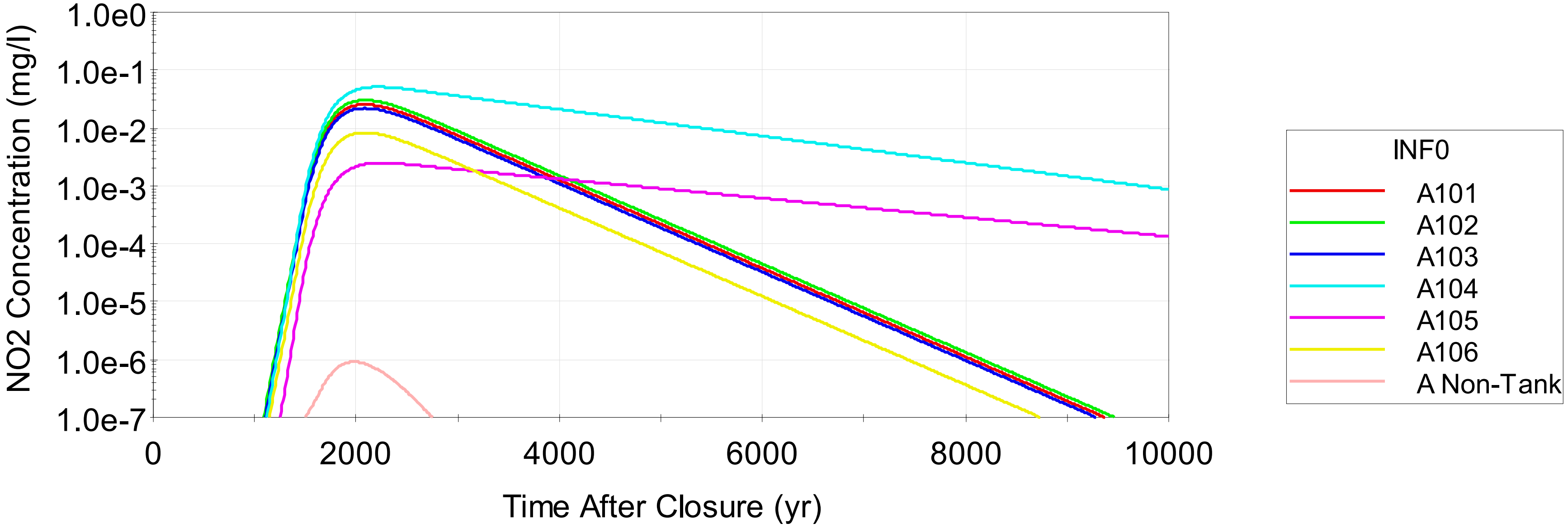

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Figure 7-26. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case INF1.

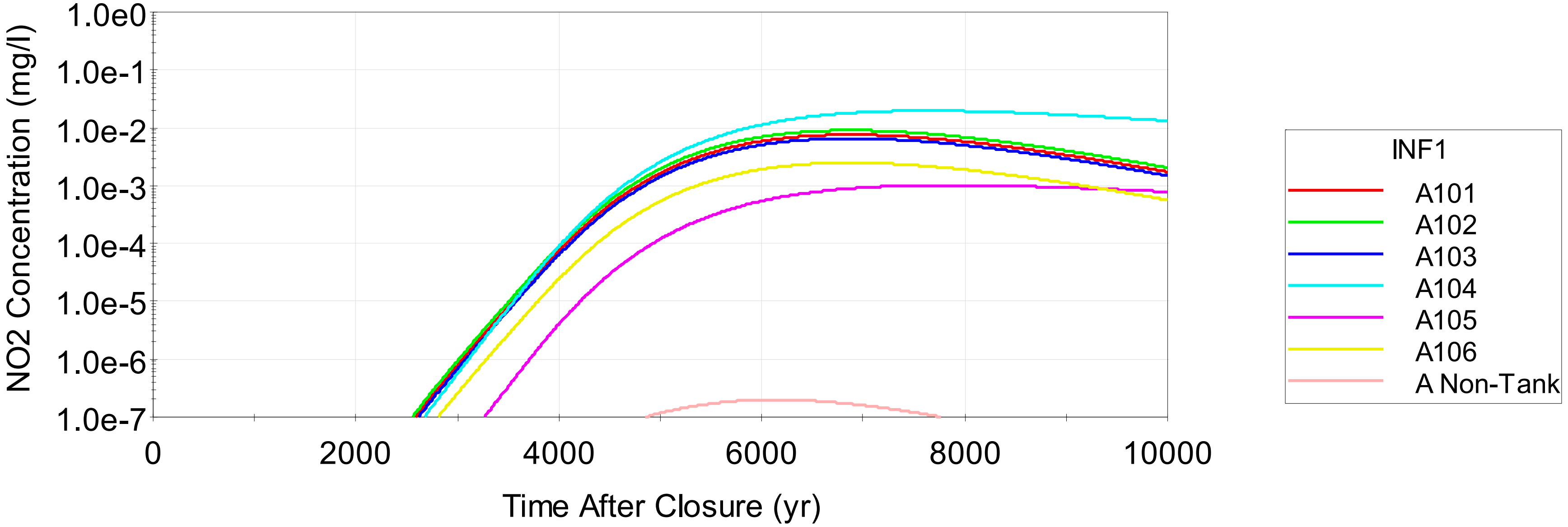

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Figure 7-27. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case INF2.

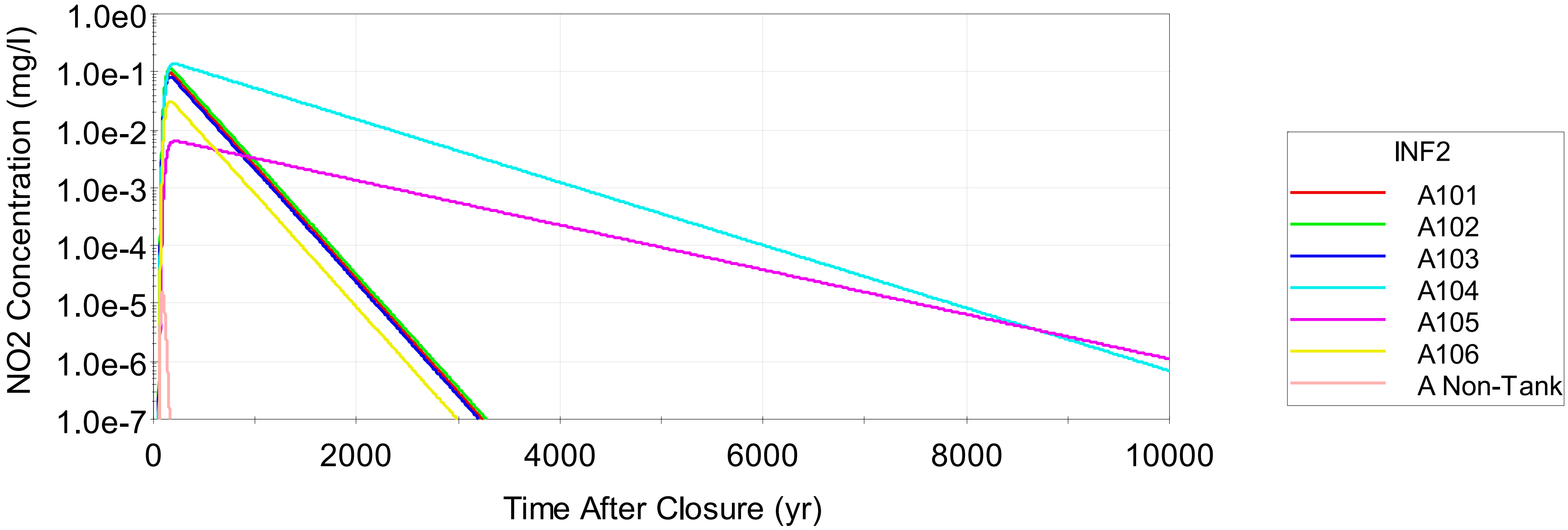

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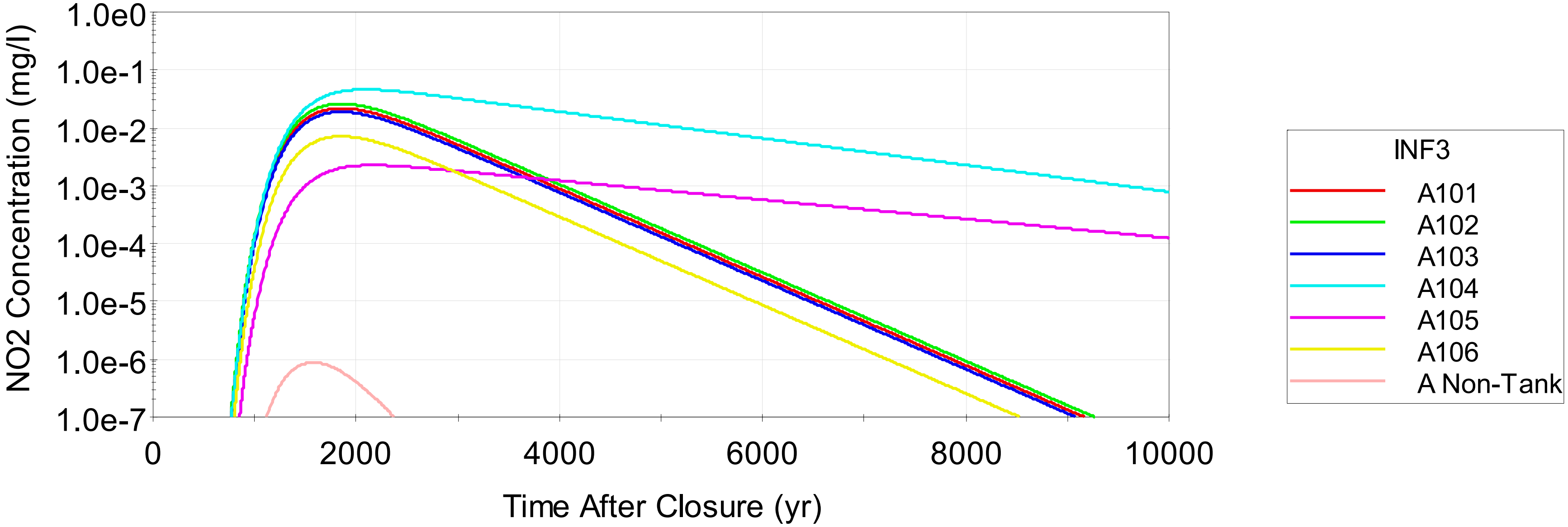
Figure 7-28. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case INF3.



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For the non-tank source, the base case inventory was developed using HTWOS tank concentrations and residual non-tank volumes. Both INV1 and INV2 cases used BBI current tank waste inventories averaged across all tanks. INV1 divided the average inventory by current non-tank waste volumes and INV2 divided the average inventory by projected non-tank residual volumes. The two inventory sensitivity cases, INV1 and INV2, are summarized in Table 7-11 along with the base case for comparison.

Table 7-11. Summary of Inventory Development for Base Case and Sensitivity Cases.

Attributes	Base Case	INV1	INV2
Tank data source	BBI current tank wastes	BBI current tank wastes	BBI current tank wastes
Volumes for tank concentrations	Current tank waste volumes	Current tank waste volumes	Current tank waste volumes
Volumes for residual waste	Projected tank residual volumes	Current tank waste volumes	Projected tank residual volumes
Non-tank data source	HTWOS for 300 m^3 residual tank wastes	BBI current tank wastes	BBI current tank wastes
Volumes for average tank concentrations	HTWOS tank residual waste volume 300 m^3	Current tank waste volumes	Current tank waste volumes
Non-tank residual volumes	Projected non-tank residual volumes	Current non-tank waste volumes	Projected non-tank residual volumes

BBI = Best-Basis Inventory HTWOS = Hanford Tank Waste Operations Simulator

Source: RPP-CALC-63247, *WMA A-AX Performance Assessment Sensitivity Analysis*, Table 4-2.

Figure 7-29 compares the groundwater concentrations of nitrite at 100 m downgradient from WMA A-AX from the base case and two inventory sensitivity cases. Case INV1, which represents a case where tanks have not been retrieved, has a substantially higher nitrite groundwater concentration than the base case or INV2. The groundwater concentration of nitrite in case INV1 is 0.63 mg/L compared to 0.14 mg/L in the base case and 0.15 mg/L in case INV2. In all cases the peak concentration occurs at roughly the same time; at about 2,120 years after closure for the base case, 2,090 years for INV2, and 2,170 years after closure for INV1.

Table 7-12 shows the peak nitrite concentrations from all sources at A Farm and AX Farm at the 100-m point of calculation for the inventory sensitivity cases and the base case.

Figure 7-30 through Figure 7-32 show the contributions of each A Farm source to the nitrite groundwater concentration at the WMA A-AX fenceline. Individual tank concentrations are the same between the base case and INV2 since the inventories are the same between the two cases. INV1 has higher nitrite groundwater concentrations throughout the model timeframe and the concentrations do not diminish as quickly over time as in the base case and INV2. This is because without retrieval, the tanks would have a greater residual waste volume, resulting in a lower release rate and slower depletion of the inventory compared to the base case and INV2. In INV1, tank A-103 has the highest residual inventory and greatest waste volume, but tank A-101 has a higher peak groundwater concentration. The slightly smaller inventory in tank A-101 compared to tank A-103 is distributed in a much smaller waste volume, which leads to faster release rates from tank A-101 compared to tank A-103.

Figure 7-29. Nitrite Groundwater Concentrations from All 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Inventory Sensitivity Cases.

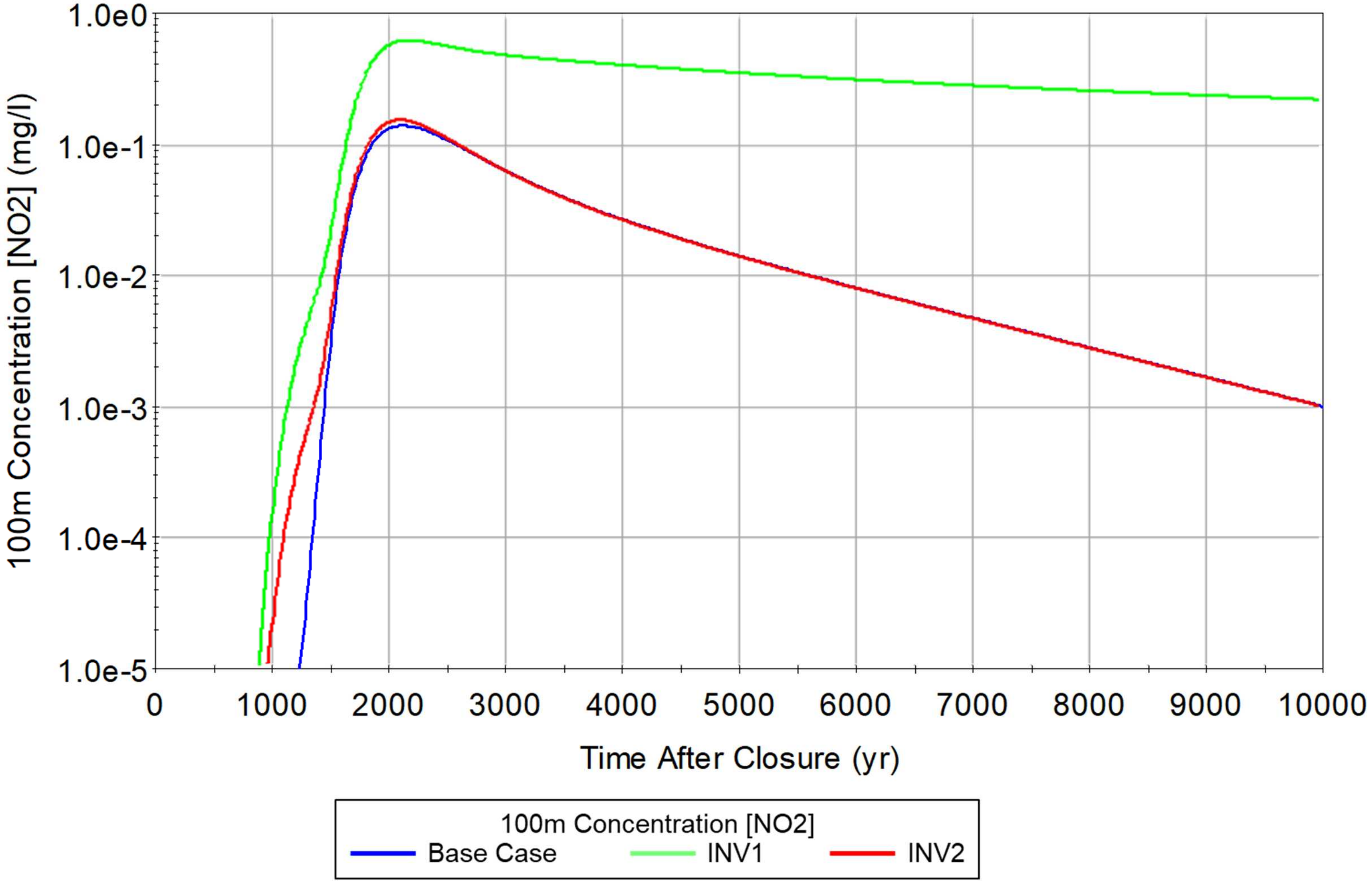

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Table 7-12. Peak Nitrite Concentration and Peak Arrival Times for Base Case (INV0), INV1, and INV2.

Farm Name	Case Name	Peak Concentration (mg/L)	Peak Time (years after closure)
241-A Tank Farm	Base Case (INV0)	0.1384	2,120
	INV1	0.6269	2,170
	INV2	0.1546	2,090
241-AX Tank Farm	Base Case (INV0)	0.0358	2,320
	INV1	0.2849	2,670
	INV2	0.0399	2,260

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Non-tank source contributions to nitrite groundwater concentrations are significantly higher in cases INV1 and INV2 compared to the base case. This is because the inventories in those cases are several orders of magnitude higher than the base case.

7.1.5.3 Grout Sensitivity Cases. The sensitivity cases described in this section investigate the effect of grout safety functions on the groundwater nitrite concentrations. Three sensitivity cases have been identified as shown in Table 7-13. The term "physical degradation" in the table means that the tank concrete shell, including the base mat and the grout infill above the waste zone, lose their flow safety function. Consequently, water is able to flow through the grout, giving rise to advective release of chemicals from the residual waste zone. Both the base case and GRT3 involve no physical degradation of the grout. Where grout degradation is assumed to occur, the physical and water flow properties of the material change to those of sand, while the geochemical characteristics remain as those of grout. In one case, GRT3, the geochemical adsorption property of the grout materials is assumed to lose their safety function to sorb chemicals in the residual waste. As a result, chemicals diffuse through the tank base mat without sorption. Note that to test each of the physical and chemical safety functions, only one function is tested in each case. The moisture contents and Darcy velocities of the vadose zone for degraded grout conditions are presented in RPP-CALC-63247.

Figure 7-33 compares the groundwater nitrite concentrations from all A Farm tanks at 100 m downgradient from WMA A-AX from the grout sensitivity cases. Compared to the base case peak concentration of 0.14 mg/L (2,120 years after closure), both GRT1 (0.38 mg/L) and GRT2 (0.29 mg/L) have higher peak concentrations and slightly earlier arrival times (1,920 years after closure for GRT1 and 1,630 years after closure for GRT2). GRT3 is exactly the same as the base case because nitrite has a grout K_d of 0 mL/g in both instances. Because GRT1 and GRT2 have their flow fields changed to a degraded condition earlier in the simulation, the resulting advective transport increases the release rate of contaminants and moves them more quickly to the water table. This results in a higher peak concentration sooner and also results in a rapid decrease in concentration after the peak than the base case. This is because the source term is depleted sooner and is moved out of the system more quickly.

Figure 7-30. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Base Case.

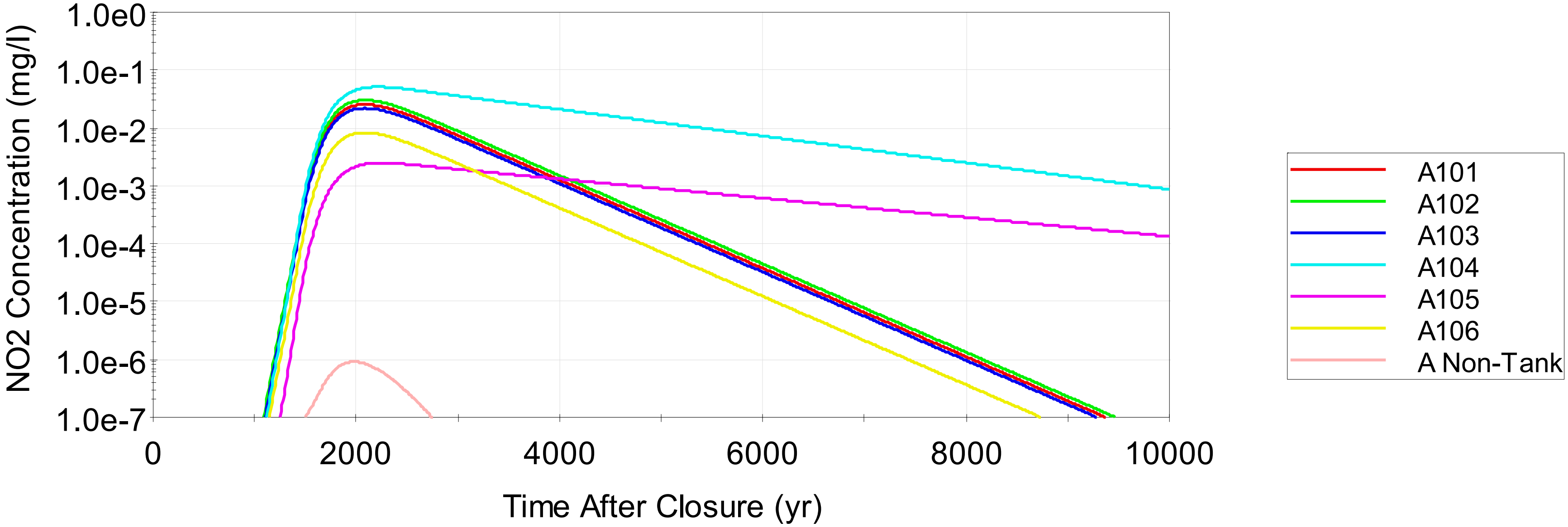

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Figure 7-31. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case INV1.

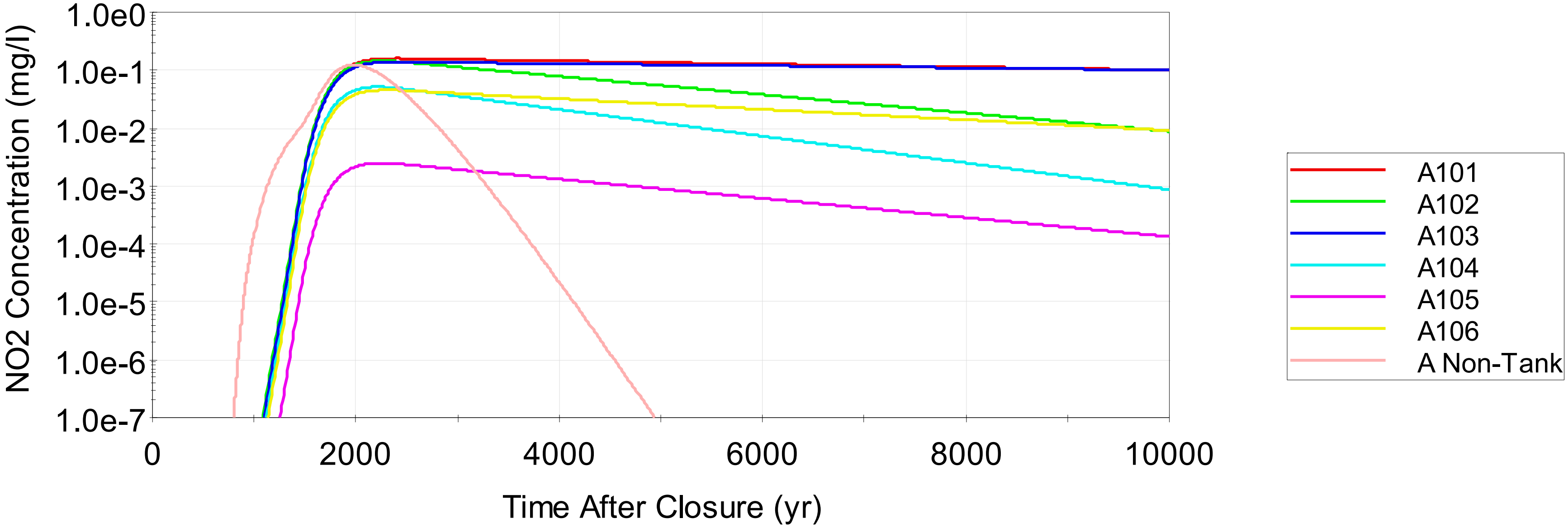

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Figure 7-32. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case INV2.

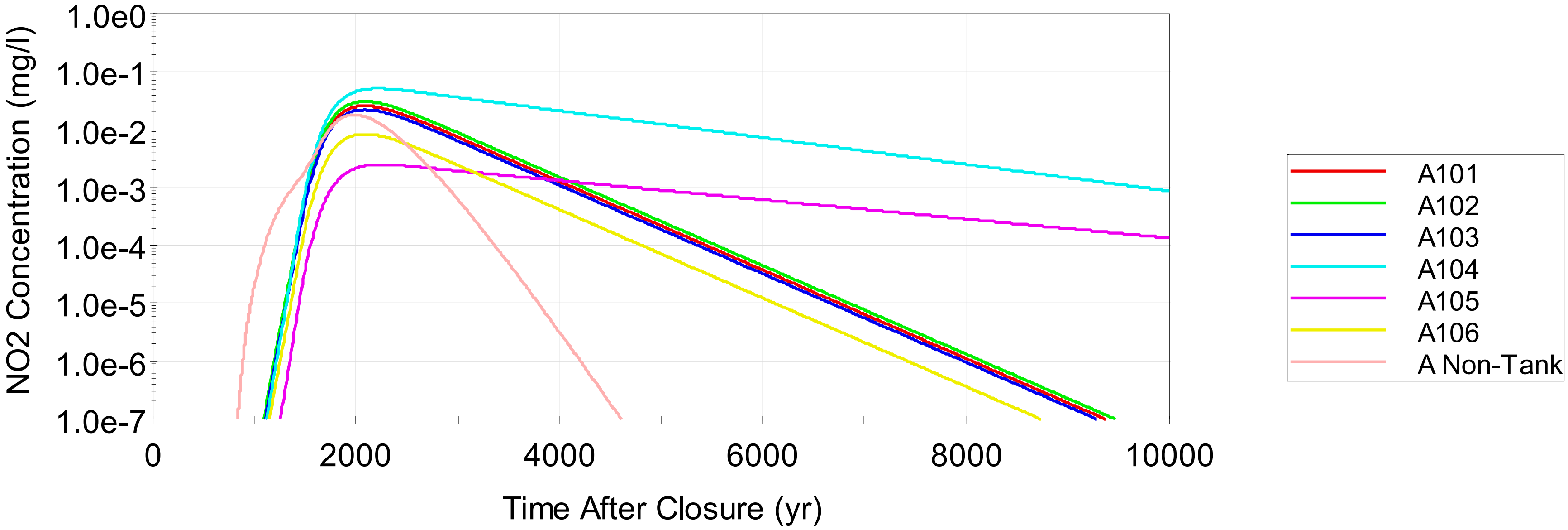

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Table 7-13. Grout Sensitivity Case Parameters.

Case ID	Time of Physical Degradation	GRT_Time* (years)	Chemical Degradation Status
GRT0 (Base Case)	No degradation	1E6	Best estimate Grout K_ds
GRT1	0-500 years (intact), 500-10,000 years (degraded)	500	Best estimate Grout K_ds
GRT2	Degraded at all times	0	Best estimate Grout K_ds
GRT3	No degradation	1E6	Grout K_ds set to 0 mL/g for all chemicals

*GRT_Time – grout degradation time.

Source: RPP-CALC-63247, *WMA A-AX Performance Assessment Sensitivity Analysis*, Table 4-14.

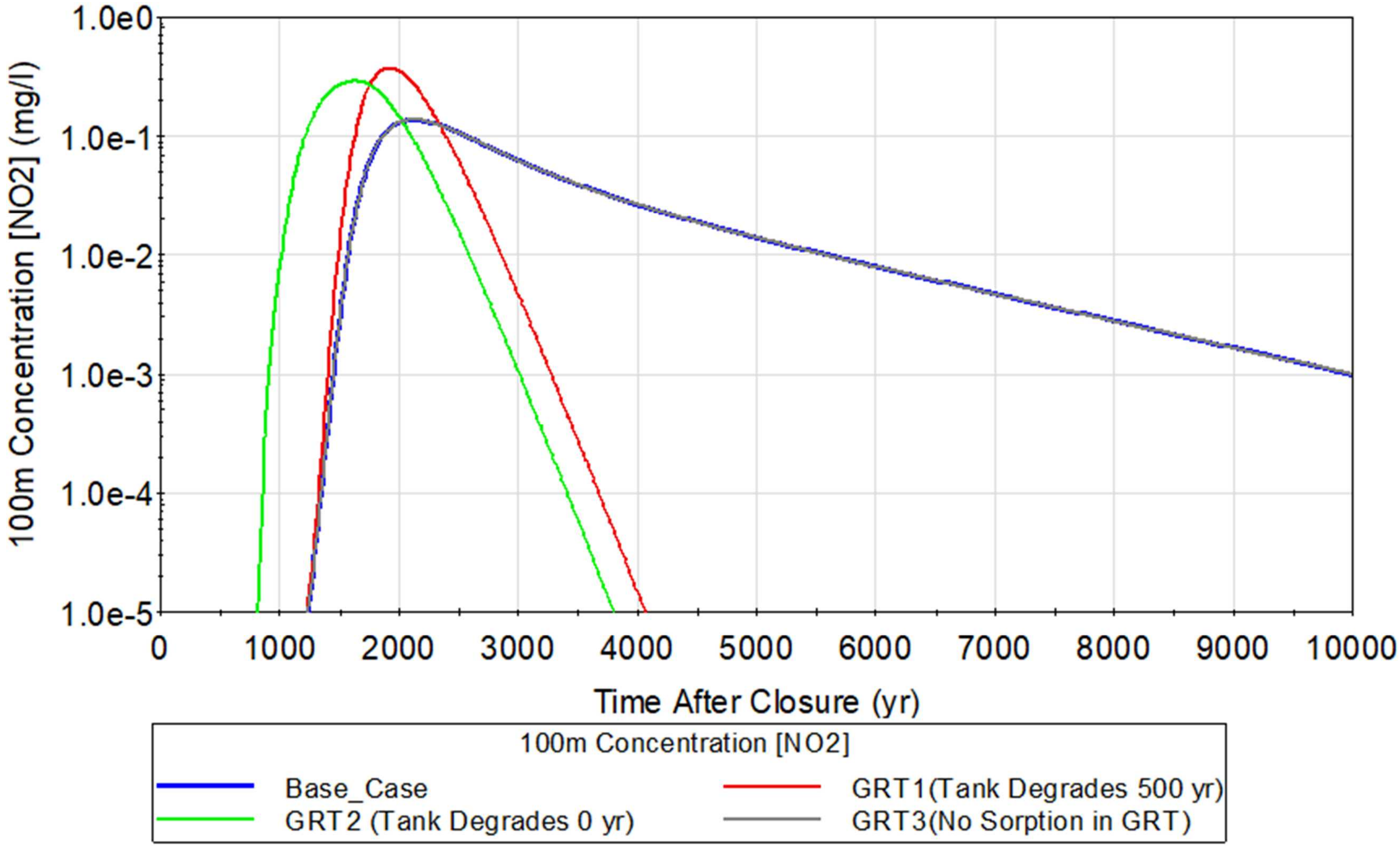
Figure 7-34 shows the groundwater total uranium concentration from all A Farm tanks at 100 m downgradient from WMA A-AX from the base case and sensitivity case GRT3. Since nitrite has a grout K_d of 0 mL/g in the base case, another chemical had to be used to examine the effects of the grout chemical safety function. Of the chemicals with an inventory greater than 0, only 4 have a grout K_d greater than zero: nickel (40 mL/g), lead (500 mL/g), strontium (1 mL/g) and uranium (0.6 mL/g). The K_d in H2 sands for all of these chemcials but uranium are high enough to prevent their transport to the water table within the 10,000 year simulation. Therefore, uranium was chosen to examine the grout chemical safety function. Figure 7-34 shows the difference between the groundwater concentrations in the GRT3 case and the base case at 100 m downgradient from WMA A-AX.

Table 7-14 shows the peak nitrite concentrations from all sources at A Farm and AX Farm at the 100-m point of calculation for the grout sensitivity cases and the base case. Table 7-15 shows the peak uranium concentration from all sources at A Farm and AX Farm at the 100-m point of calculation for the GRT3 case and the base case.

Figure 7-35 through Figure 7-38 show the A Farm tank contributions to groundwater nitrite concentration 100 m downgradient from WMA A-AX by sensitivity case. Each tank's peak concentration is proportional to its nitrite inventory. Nitrite concentrations from tank A-104 and tank A-105 are different from the other A Farm tanks because of their larger residual waste volumes.

7.1.5.4 Tank Shell Sensitivity Case. The concrete tanks in A Farm and AX Farm are constructed with an inner steel liner. The base case analysis takes no credit for this tank liner in preventing or delaying the release of waste constituents to the vadose zone. With this assumption, the contaminants are released from the time of closure. The tank-shell sensitivity case (TS1) is designed to investigate the tank integrity safety function. The approach taken in this study is to delay release of waste constituents for a certain time period. Specifically, it is assumed that each tank's steel liner lifetime is 5,000 years, during which no releases occur. After 5,000 years, the releases by diffusion are enabled.

Figure 7-33. Nitrite Groundwater Concentrations from All 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Grout Sensitivity Cases.



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Note: GRT3 and Base_Case overlay one another because they simulate the same conditions for nitrite (no sorption in the base mat).

Figure 7-34. Uranium Groundwater Concentrations from All 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Sensitivity Case GRT3.

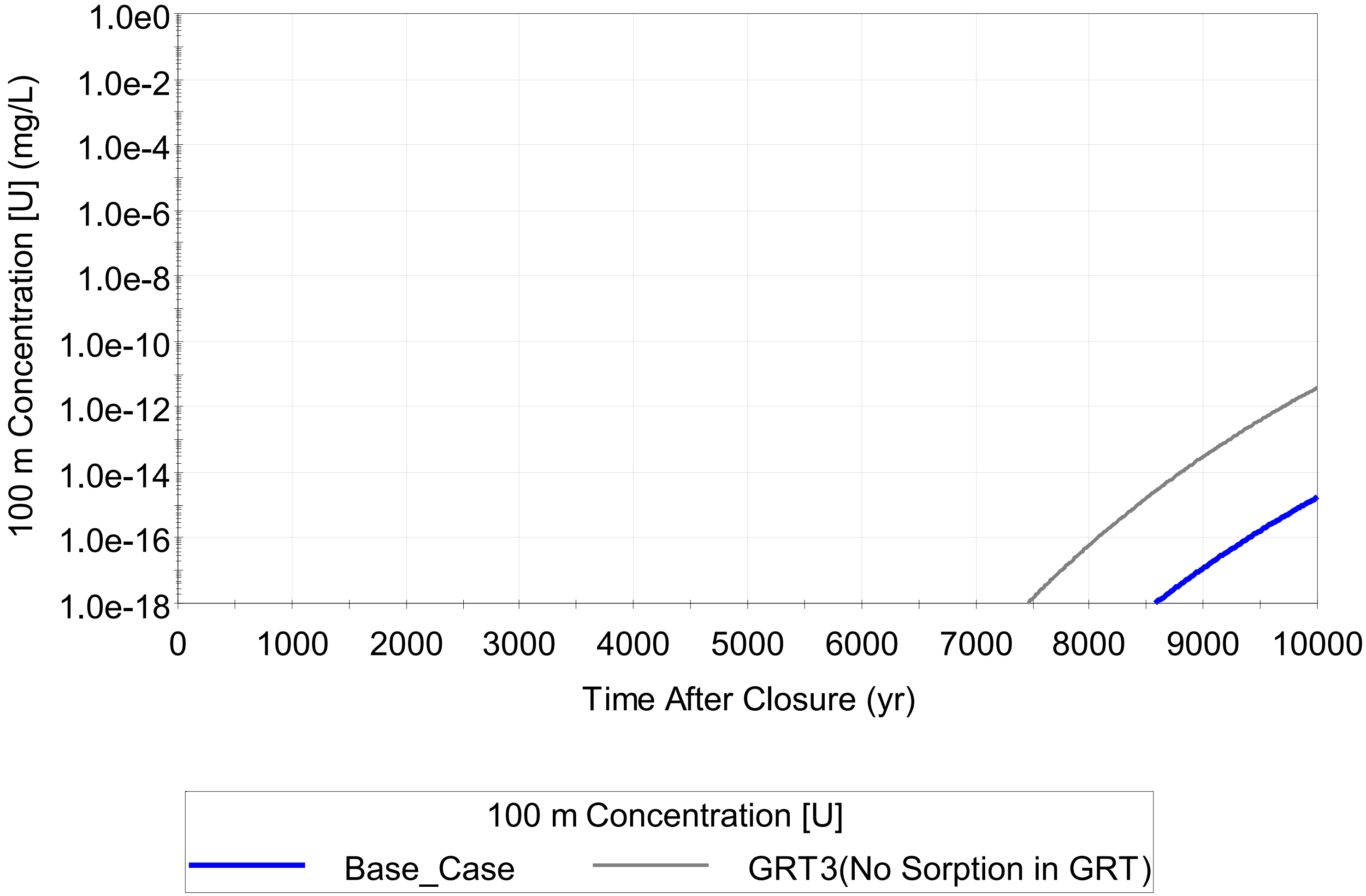

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Table 7-14. Peak Nitrite Concentration and Peak Arrival Times for the Grout Sensitivity Cases and the Base Case.

Farm Name	Case Name	Peak Concentration (mg/L)	Peak Time (years after closure)
241-A Tank Farm	Base Case	0.1384	2,120
	GRT1	0.3782	1,920
	GRT2	0.2899	1,630
241-AX Tank Farm	Base Case	0.0358	2,320
	GRT1	0.0766	1,930
	GRT2	0.0722	1,640

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Table 7-15. Peak Uranium Concentration and Peak Arrival Times for GRT3 and Base Case.

Farm Name	Case Name	Peak Concentration (mg/L)	Peak Time (years)
241-A Tank Farm	Base Case	1.72E-15	10,000
	GRT3	3.81E-12	10,000
241-AX Tank Farm	Base Case	2.81E-18	10,000
	GRT3	2.57E-14	10,000

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Figure 7-39 compares the nitrite groundwater concentration at the 100-m downgradient point of calculation between the base case and the tank shell sensitivity case. The TS1 peak concentration is about 15% lower and occurs much later in time – about 5,000 years later than the base case. This is not surprising since the tank shell prevents any release for 5,000 years and the vadose zone conditions are the same, resulting in a nearly identical breakthrough curve that is just 5,000 years later than the base case. Diffusive releases from the tank bottom are not impacted by the change in net infiltration once the surface barrier degrades. In the base case, the sudden change in net infiltration rates rapidly mobilized slowly moving contaminants that had previously been released from the tanks. This resulted in a slightly higher peak groundwater concentration that is not evident in the TS1 case. Figure 7-40 shows each source's contribution to the nitrite concentration in the TS1 case. The non-tank source breakthrough curve is identical to the base case since the non-tank source has no tank shell. The tank breakthrough curves are nearly identical to their base case counterparts, just offset by 5,000 years.

Figure 7-35. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Base Case.

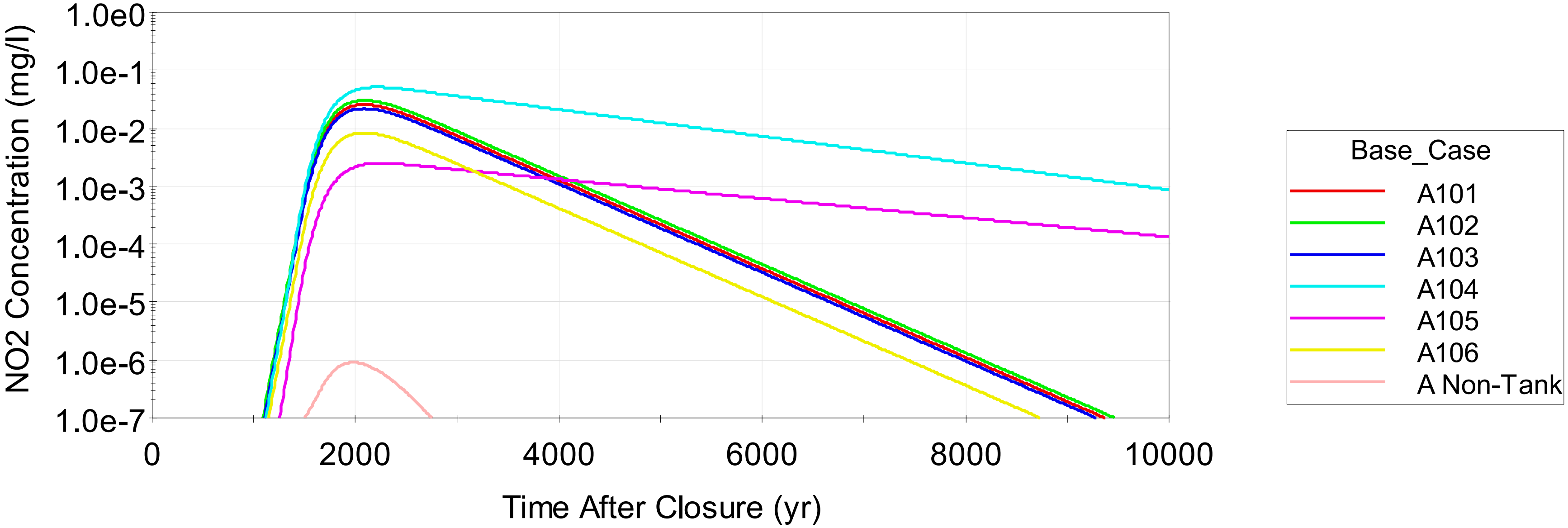

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Figure 7-36. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case GRT1.

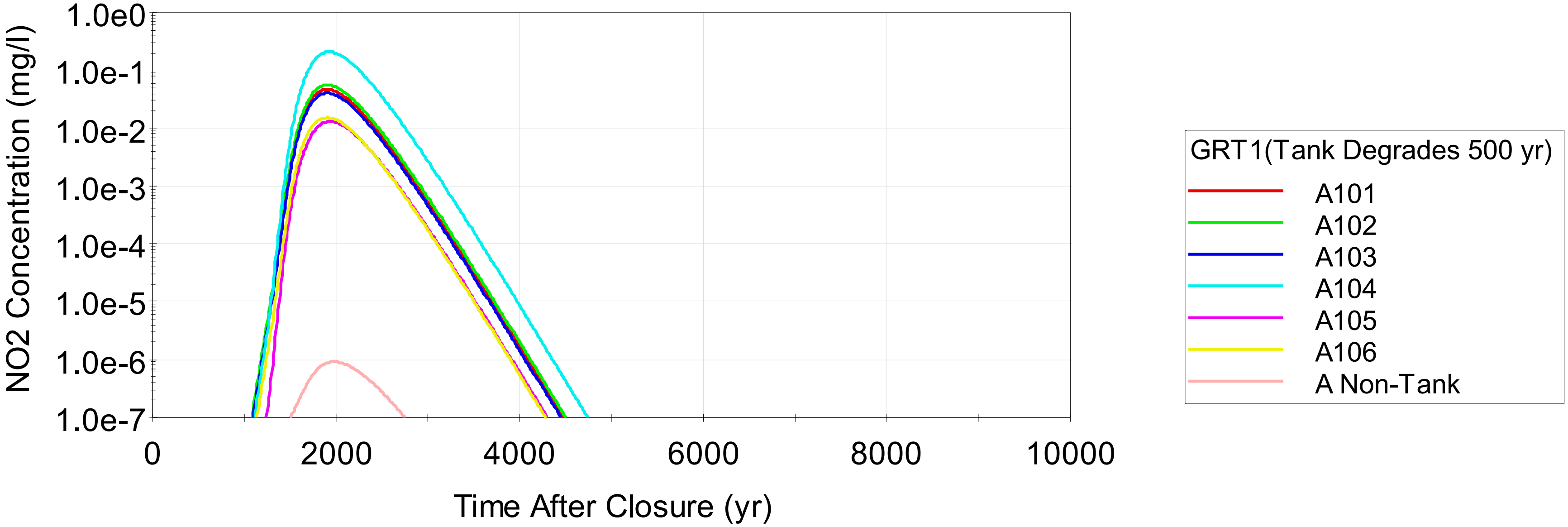

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Figure 7-37. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case GRT2.

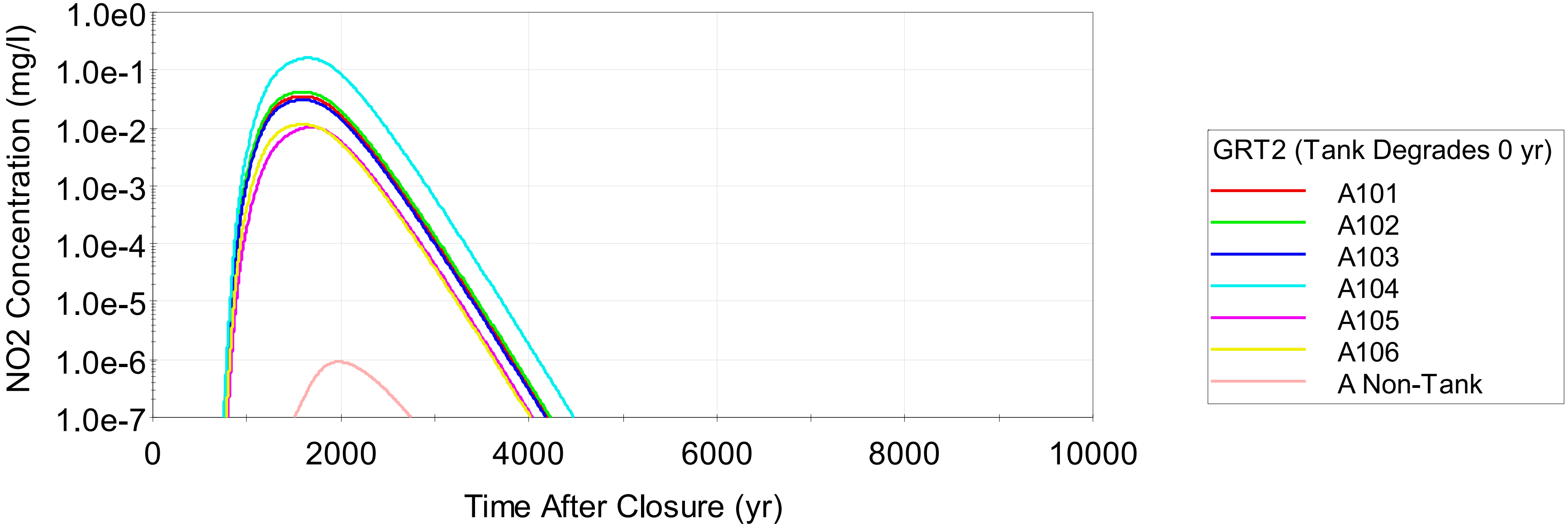

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Figure 7-38. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case GRT3.

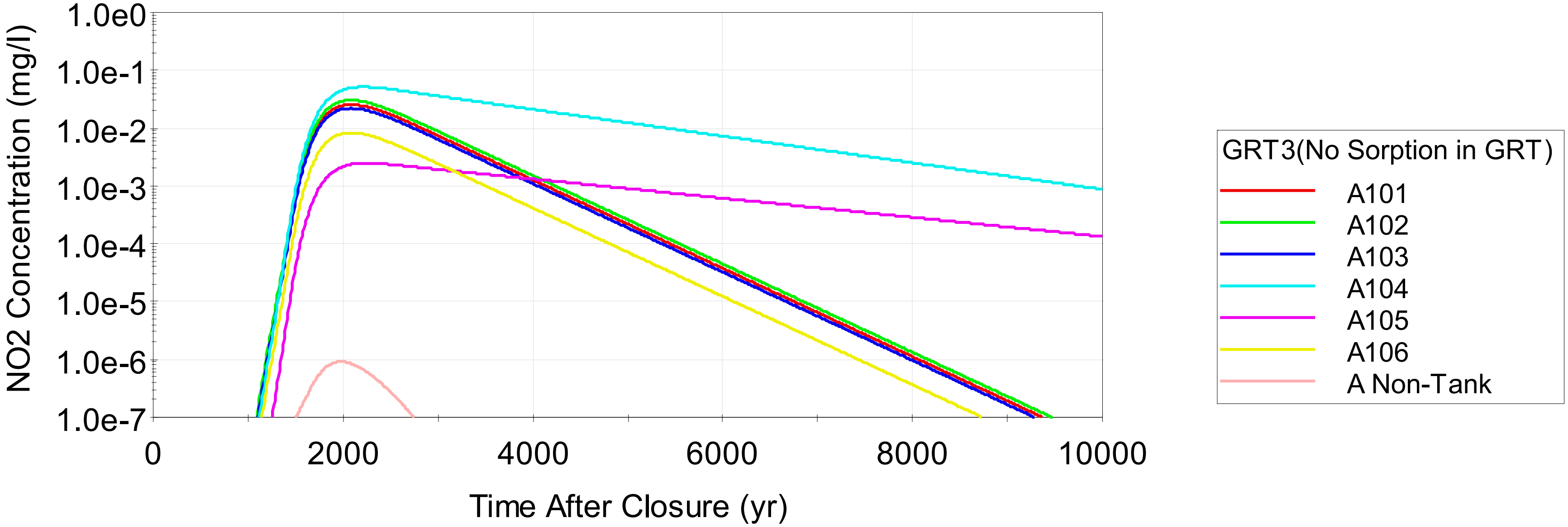

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Figure 7-39. Nitrite Groundwater Concentrations from All 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Tank Shell Sensitivity Case.

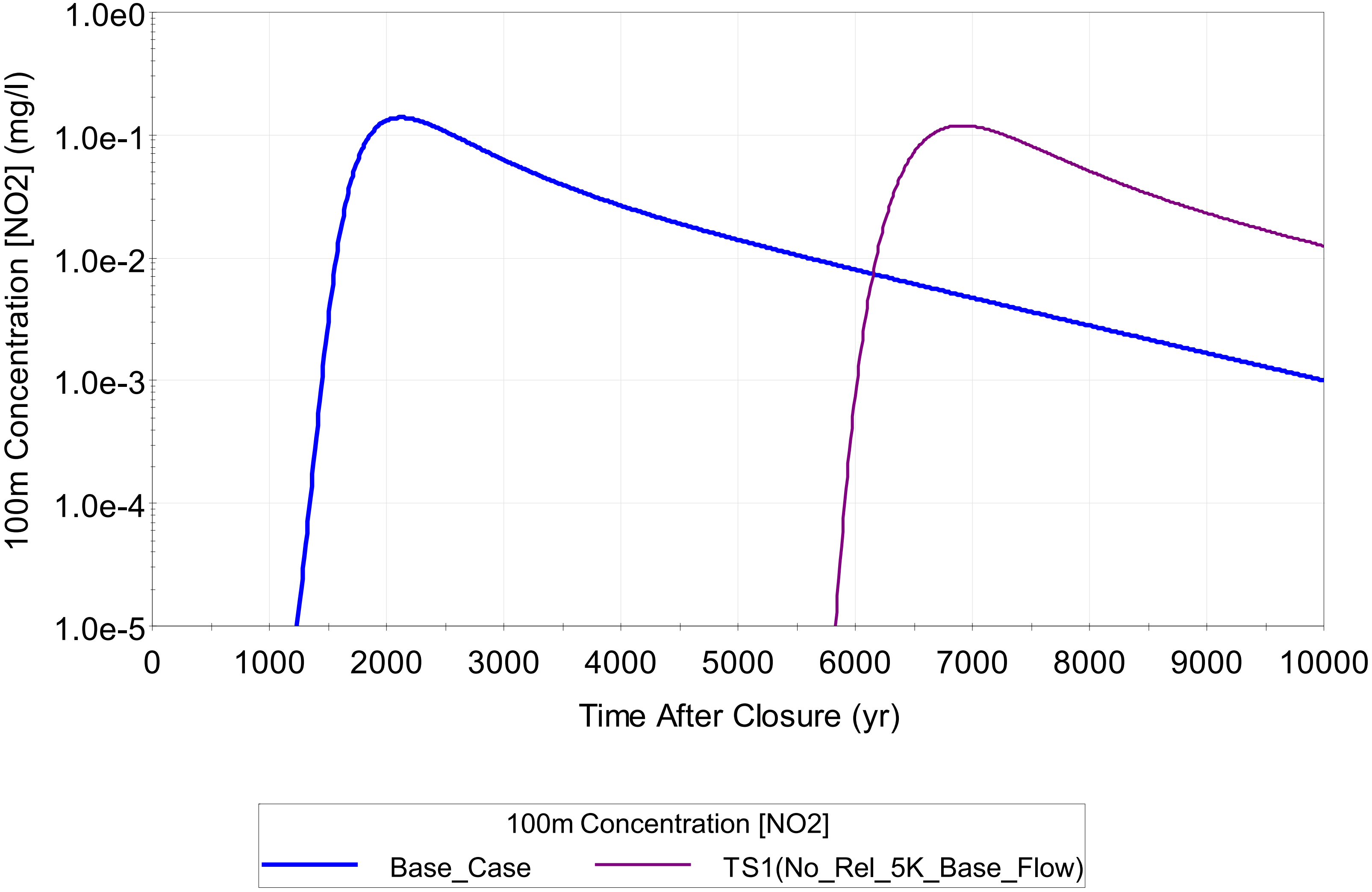

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Figure 7-40. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case TS1.

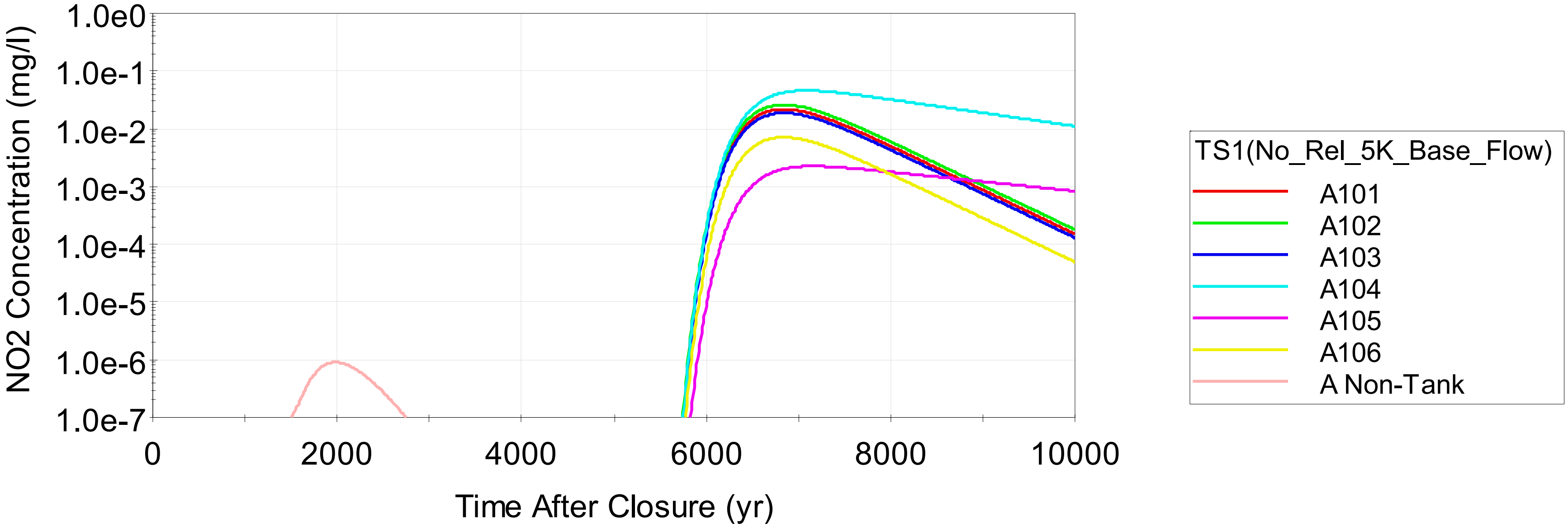

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Table 7-16 shows the peak nitrite concentrations from all sources at A Farm and AX Farm at the 100-m point of calculation for the tank shell sensitivity case and the base case.

Table 7-16. Peak Nitrite Concentration and Peak Arrival Times for TS1 and the Base Case.

Farm	Case Name	Peak Dose (mg/L)	Peak Time (years)
241-A Tank Farm	Base Case	0.1384	2,120
	TS1	0.1193	6,910
241-AX Tank Farm	Base Case	0.0358	2,320
	TS1	0.0327	7,100

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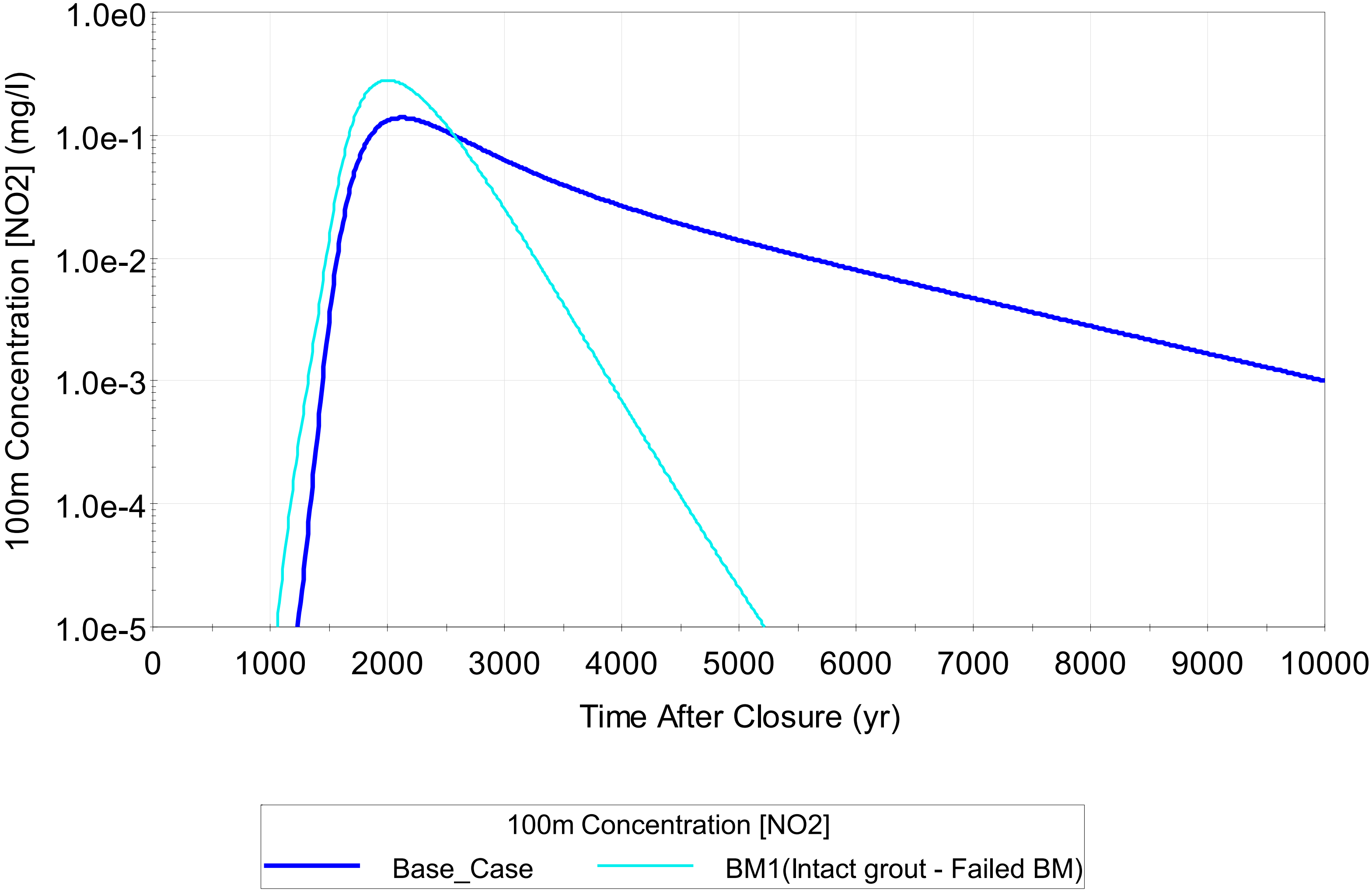
7.1.5.5 Base Mat Sensitivity Case. The base case assumes that there is no advective transport in the concrete tank base mat over the 10,000-year period of simulation, leaving diffusion as the only mechanism by which residual waste constituents are able to be released. This assumption is consistent with the related assumption that concrete remains intact over this period of time. If, however, the concrete is degraded such that its permeability increases, it is possible that the surrounding unsaturated flow may find a pathway through the base mat. The base mat sensitivity case (designated as BM1) is designed to study the effect of degraded base mats (by allowing advection through the base mat) on the release and transport of residual waste constituents.

Figure 7-41 compares nitrite concentrations from all A Farm sources at 100 m downgradient from A-AX Farm between the base case and the BM1 case. The peak nitrite concentration in the BM1 case is 0.28 mg/L 2,000 years after closure, which is about double the concentration in the base case and arriving about 120 years sooner. By allowing advection through the basemat, the BM1 case has an increased release rate from the source term compared to the base case. This advection-dominated release results in a higher concentration of nitrite reaching the groundwater sooner than in the base case.

Table 7-17 shows the peak nitrite concentrations from all sources at A Farm and AX Farm at the 100-m point of calculation for the base mat sensitivity case and the base case.

Figure 7-42 shows the contribution of each A Farm source to the 100-m nitrite groundwater contribution. Each source’s contribution is proportional to the source’s inventory and the breakthrough curves of tank A-104 and tank A-105 are different from the other sources because of the increased waste volume in those tanks.

Figure 7-41. Nitrite Groundwater Concentrations from All 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Base Mat Sensitivity Case.



BM = base mat

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Table 7-17. Peak Nitrite Concentration and Peak Arrival Times for BM1 and Base Case.

Farm Name	Case Name	Peak Dose (mg/L)	Peak Time (years)
241-A Tank Farm	Base Case	0.1384	2,120
	BM1	0.2798	2,000
241-AX Tank Farm	Base Case	0.0358	2,320
	BM1	0.0618	2,140

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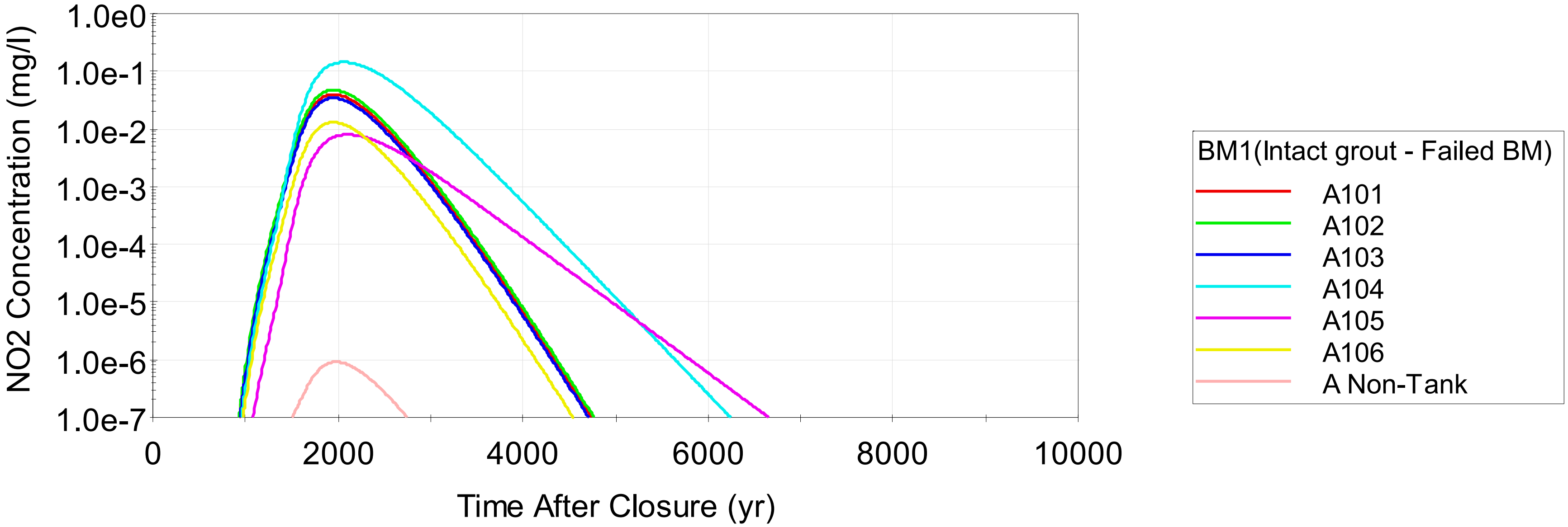
7.2 CONCLUSIONS

Cancer risks and non-cancer hazards to a receptor using groundwater 100 m from the closed WMA A-AX under the EPA's residential tap water scenario were calculated using the WMA A-AX system model developed in GoldSim©.

No cancer risks were identified because no carcinogenic chemicals reach to POC within the model's 10,000-year time frame.

The peak chemical non-cancer HI is about 0.035, peaking at 2,120 years post-closure, and is less than the target HI of one. This HI includes the contribution from all A Farm sources and occurs at the WMA A-AX fenceline. Early in the simulation (0 to 1,000 years post-closure), the HI is driven by chromium from A Farm non-tank sources. For the remainder of the simulation (1,000 to 10,000 years post-closure), HI is still driven by chromium from A Farm sources at its peak (in less than 2,000 years post closure), but nitrite from tank sources, primarily tank A-104, becomes the predominant contributor to HI through the rest of the simulation. Similar results are also observed for AX Farm.

Figure 7-42. Nitrite Groundwater Concentrations by 241-A Farm Tanks at 100 meters Downgradient from Waste Management Area A-AX – Case BM1.



BM = base mat
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The sensitivity analysis results for the various cases indicate that the peak groundwater nitrite concentration during the compliance period is mostly sensitive to the recharge rate for the non-tank sources and advective release due to degraded grout for the tank sources. These correspond to INF2 (100 mm/yr recharge rate throughout 10,000-year period) and GRT1 (the tank grout degraded since 500 years post-closure) cases. Both of these cases result in earlier arrival of nitrite at the water table and would also result in earlier arrival of all other constituents at the water table. Chemicals with moderate sorption in the vadose zone that do not reach the groundwater in 10,000 years could reach the water table in 10,000 years under higher vadose zone flow rates. The maximum nitrite concentration at 100 m downgradient during the compliance period (with contributions from either farm) for INF2 is about 0.45 mg/L, which is over seven orders of magnitude higher than the base case peak concentration (with contributions from either farm) of 3×10^{-8} mg/L and about a factor of two lower than the MCL. Since the hazard quotient for nitrite during the compliance period (with contributions from both farms) is 5×10^{-9}, a seven-order-of-magnitude increase would still be below the performance objective. From Figures 4-7 to 4-14 in RPP-CALC-63247 and Figure 7-13 in RPP-CALC-62538, *WMA A-AX Performance Assessment Groundwater Pathway Dose Calculation*, uranium concentrations in the groundwater increase by about eight orders of magnitude in INF2 over the base case. An increase of eight orders of magnitude in total uranium concentration in the groundwater would not cause the HQ for total uranium (Table 7-5) to exceed 1.0.

In the post-compliance period, the peak groundwater nitrite concentration is mostly sensitive to post-retrieval inventory changes and the recharge rate for the non-tank sources. These correspond to INV1 (no retrieval), INF2 (100 mm/yr recharge rate throughout 10,000-year period) and GRT1 (the tank grout degraded since 500 years post-closure) cases. The maximum nitrite concentration at 100 m downgradient during the post-compliance period (with contributions from either farm) for INV1 is 0.62 mg/L, which is about 5 times greater than the peak base case concentration of 1.3×10^{-1} mg/L from either farm at 100 m downgradient in the same timeframe. The peak concentration in the INV1 case is still well below the MCL of 4.5 mg/L. Since the peak base case nitrite HQ at 100 m downgradient is 3×10^{-2}, 5 times that value would still be well under the performance objective.

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RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-61497, in process, *Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington*, Draft A, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58293, 2017, *Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58693, in process, *Engineered System Data Package for Waste Management Area A-AX*, Preliminary Draft, Washington River Protection Solutions, LLC, Richland, Washington.

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TFC-ESHQ-ENV_FS-C-05, "Preparation and Issuance of Model Package Reports and Environmental Model Calculation Files," Washington River Protection Solutions, LLC, Richland, Washington.

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WAC 173-340-900, "Tables," *Washington Administrative Code*, as amended.

WAC 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)," *Washington Administrative Co*, as amended.

WSRC-STI-2007-00369, 2007, *Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*, Rev. 0, Savannah River National Laboratory, Aiken, South Carolina.

WSRC-STI-2007-00607, 2007, *Chemical Degradation Assessment of Cementitious Materials for the HLW Tank Closure Project (U)*, Rev. 0, Washington Savannah River Company/Savannah River National Laboratory, Aiken, South Carolina.

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ATTACHMENT 1

SOFTWARE INSTALLATION AND CHECKOUT FORMS

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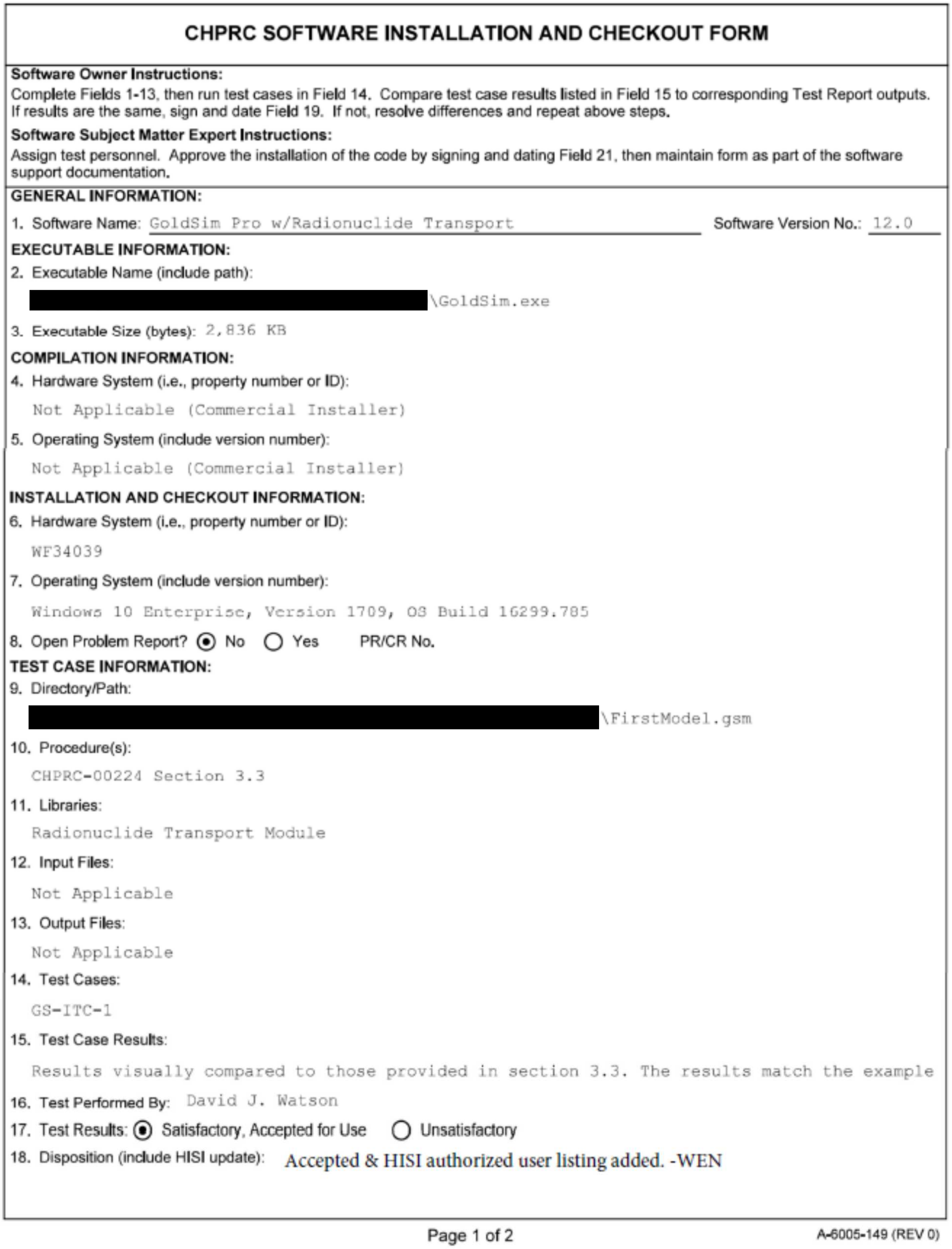

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: GoldSim Pro w/Radionuclide Transport Software Version No.: 12.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):
   [redacted]\GoldSim.exe
3. Executable Size (bytes): 2,836 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):
   Not Applicable (Commercial Installer)
5. Operating System (include version number):
   Not Applicable (Commercial Installer)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):
   WF34039
7. Operating System (include version number):
   Windows 10 Enterprise, Version 1709, OS Build 16299.785
8. Open Problem Report? ● No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:
   [redacted]\FirstModel.gsm
10. Procedure(s):
    CHPRC-00224 Section 3.3
11. Libraries:
    Radionuclide Transport Module
12. Input Files:
    Not Applicable
13. Output Files:
    Not Applicable
14. Test Cases:
    GS-ITC-1
15. Test Case Results:
    Results visually compared to those provided in section 3.3. The results match the example
16. Test Performed By: David J. Watson
17. Test Results: ● Satisfactory, Accepted for Use ○ Unsatisfactory
18. Disposition (include HISI update): Accepted & HISI authorized user listing added. -WEN

Page 1 of 2 A-6005-149 (REV 0)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: GoldSim Pro w/Radionuclide Transport Software Version No.: 12.0

Prepared By:

19. WILLIAM NICHOLS (Affiliate) Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2018.11.29 14:33:22 -08'00'

Software Owner (Signature)	Print	Date

20. Test Personnel:

Sign	Print	Date
	David J. Watson	29November2018

Approved By:

21.

Software SME (Signature)	Print	Date

ATTACHMENT 2

TANK RESIDUAL WASTE CHARACTERISTICS

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Table Att-2-1. Residual Inventories Used in Waste Management Area A-AX Tap Water Scenario Calculations (kilograms).

Chemical	Tanks ("241-" prefix omitted)										A Farm Non-Tank Sources	AX Farm Non-Tank Sources
	A-101	A-102	A-103	A-104	A-105	A-106	AX-101	AX-102	AX-103	AX-104		
Al	4.42E+02	5.36E+02	2.40E+02	7.08E+03	8.28E+03	3.81E+02	4.18E+02	2.14E+02	3.82E+02	9.68E+02	3.11E+03	1.11E+03
B	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CN	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr	6.47E+01	1.13E+02	1.88E+01	1.58E+02	3.56E+02	7.21E+01	3.55E+01	9.20E+00	5.39E+01	1.06E+01	4.17E+02	1.25E+02
F	9.68E+00	3.72E+00	8.18E+00	1.92E+00	1.68E+01	3.88E+00	1.01E+01	5.34E+00	1.36E+01	1.85E+00	1.74E-04	9.26E-05
Fe	7.22E+00	3.22E+02	1.20E+01	2.59E+04	1.92E+04	6.83E+02	1.05E+01	5.77E+02	1.15E+02	4.97E+03	2.20E+03	1.13E+03
Hg	3.34E-02	6.88E-02	1.86E-02	3.20E+01	2.14E+01	6.72E+00	1.11E-01	6.85E-01	1.33E-01	3.01E+00	7.47E-05	3.77E-06
Mn	2.03E+00	6.32E+01	2.06E+00	3.63E+03	6.49E+02	3.30E+01	3.93E-01	4.71E+01	1.56E+01	8.61E+01	2.37E+02	5.20E+01
Ni	3.21E+00	9.43E+00	1.86E+00	1.68E+03	1.55E+03	2.63E+01	1.20E+00	1.34E+01	6.83E+00	2.67E+02	1.64E+02	5.47E+01
NO_2	1.31E+03	1.56E+03	1.13E+03	5.88E+03	3.73E+02	4.29E+02	1.38E+03	4.57E+02	1.36E+03	4.12E+01	4.08E-02	9.27E-03
NO_3	2.40E+03	1.73E+03	1.59E+03	3.02E+02	9.53E+03	1.16E+03	2.56E+03	2.33E+03	1.73E+03	8.38E+02	5.04E-02	1.85E-02
Pb	3.22E+00	2.22E+01	2.22E+00	5.65E+01	1.54E+03	3.17E+01	1.47E+00	4.00E+01	9.81E+00	1.70E+02	4.26E-04	2.02E-04
Sr	1.80E-01	9.29E-01	9.15E-02	4.21E+01	5.34E+01	3.01E+00	3.21E-02	1.05E+01	1.16E+00	1.75E+01	4.08E+00	5.50E+00
Se	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sn	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TBP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U (Total)*	1.26E+01	4.53E+02	1.74E+01	1.52E+03	2.58E+00	1.71E+01	1.13E+01	4.86E+01	4.88E+00	6.02E+01	4.38E+02	1.74E+01

*Uranium mass calculated from the activity inventories of all uranium isotopes reported in the sources.

Sources: RPP-CALC-62319, *Residual Waste Source Inventory Term for the Waste Management Area A-AX Performance Assessment Inventory Case 1* (tank inventories);
RPP-RPT-58293, *Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates* (non-tank source inventories).

Table Att-2-2. Residual Waste Parameters Used in Waste Management Area A-AX Tap Water Scenario Calculations.

Source	Residual Waste Volume (L)[a]	Cross-sectional Area (m^2)[b]
Tank A-101	1.02E+04	4.10E+02
Tank A-102	1.02E+04	4.10E+02
Tank A-103	1.02E+04	4.10E+02
Tank A-104	9.30E+04	4.10E+02
Tank A-105	1.39E+05	4.10E+02
Tank A-106	1.02E+04	4.10E+02
Tank AX-101	1.02E+04	4.10E+02
Tank AX-102	1.02E+04	4.10E+02
Tank AX-103	1.02E+04	4.10E+02
Tank AX-104	1.02E+04	4.10E+02
A Non-Tank	9.66E+03	1.10E+04
AX Non-Tank	4.10E+03	6.64E+03

[a] Tank residual waste volumes from RPP-CALC-62319, *Residual Waste Source Inventory Term for the Waste Management Area A-AX Performance Assessment Inventory Case 1*, Table 4-5. Non-tank residual waste volumes from RPP-CALC-62319, Table 4-6.

[b] Tank and non-tank cross-sectional area from RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*, Section 3.2.2.

REFERENCES

RPP-CALC-62319, in process, *Residual Waste Source Inventory Term for the Waste Management Area A-AX Performance Assessment Inventory Case 1*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58293, 2017, *Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60885, in process, *Model Package Report System Model for the WMA A-AX Performance Assessment*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

ATTACHMENT 3

TAP WATER SCENARIO PARAMETER INPUTS

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Table Att-3-1. Scenario-specific Parameters Used in the Waste Management Area A-AX Residential Tap Water Scenario System Model.

Parameter	Equation Symbol	Value	Units	GoldSim© Element Name	Reference
Exposure Frequency, Exposure Duration, and Exposure Time Variables					
Exposure frequency – resident	EF_r	350	days/year	EF_r	RPP-ENV-58813, Rev. 1, Table H-1
Exposure duration – resident	ED_r	26	year	ED_r	RPP-ENV-58813, Rev. 1, Table H-1
Exposure duration – adult resident	ED_{r-a}	20	year	ED_ra	RPP-ENV-58813, Rev. 1, Table H-1
Exposure duration – child resident	ED_{r-c}	6	year	ED_rc	RPP-ENV-58813, Rev. 1, Table H-1
Immersion event frequency	EV_r	1	events/day	EV_r	RPP-ENV-58813, Rev. 1, Table H-1
Resident exposure time	ET_r	24	hrs/day	ET_r	RPP-ENV-58813, Rev. 1, Table H-1
Carcinogenic averaging time – resident	AT_c	25,550	days	AT_c	RPP-ENV-58813, Rev. 1, Table H-2
Noncarcinogenic averaging time – resident	AT_{nc}	2,190	days	AT_nc	RPP-ENV-58813, Rev. 1, Table H-2
Inhalation and Ingestion Rates					
Drinking water ingestion rate – adult resident	IRW_{r-a}	2.5	L/day	IRW_ra	RPP-ENV-58813, Rev. 1, Table H-1
Drinking water ingestion rate – child resident	IRW_{r-c}	0.78	L/day	IRW_rc	RPP-ENV-58813, Rev. 1, Table H-1
Immersion event time / Event duration – adult resident	$t_{r-a-event}$	0.71	hours/event	t_event_ra	RPP-ENV-58813, Rev. 1, Table H-1
Immersion event time / Event duration – child resident	$t_{r-c-event}$	0.54	hours/event	t_event_rc	RPP-ENV-58813, Rev. 1, Table H-1
Inhalation Pathway					
Andelman Volatilization Factor	K	0.5	L/m^3	K	RPP-ENV-58813, Rev. 1, Table H-1
Skin Surface Area and Dermal Absorbed Dose Variables					
Skin surface area – adult resident	SA_{r-a}	20,900	cm^2	SA_ra	RPP-ENV-58813, Rev. 1, Table H-2
Skin surface area – child resident	SA_{r-c}	6,378	cm^2	SA_rc	RPP-ENV-58813, Rev. 1, Table H-2
Body weight – adult	BW_a	80	kg	BW_a	RPP-ENV-58813, Rev. 1, Table H-2
Body weight – child	BW_c	15	kg	BW_c	RPP-ENV-58813, Rev. 1, Table H-2

RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*.

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REFERENCE

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

ATTACHMENT 4

CONTAMINANT-SPECIFIC EXPOSURE PATHWAY PARAMETER INPUTS USED FOR THE TAP WATER SCENARIO

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Table Att.4-1. Chemical-Specific Parameters Used in the Waste Management Area A-AX Residential Tap Water Scenario System Model.

GoldSim© Element Name →	**RfDo**	**Sfo**	**RfCi**[a]	**IUR**	**GIABS_CHEM**	**Kp**
Chemical Name	**Oral Reference Dose (RfDo) (mg/kg-day)**	**Oral Cancer Slope Factor (CSFo) (mg/kg-day)$^{-1}$**	**Inhalation Reference Concentration (RfC) (mg/m^3)**	**Inhalation Unit Risk (IUR) (µg/m^3)$^{-1}$**	**Fraction of Contaminant Absorbed in GI Tract (GIABS) (unitless)**	**Dermal permeability coefficient (Kp) (cm/hr)**
Aluminum	1	—[b]	—	—	1	0.001
Boron	0.2	—	—	—	1	0.001
Chromium	1.5	—	—	—	0.013	0.001
Cobalt	0.0003	—	—	—	1	0.0004
Cyanide	0.0006	—	0.0008	—	1	0.001
Fluoride	0.06	—	—	—	1	0.001
Iron	0.7	—	—	—	1	0.001
Lead	—	—	—	—	1	0.0001
Manganese	0.024	—	—	—	0.04	0.001
Mercury	0.0003	—	—	—	0.07	0.001
Nickel	0.02	—	—	—	0.04	0.0002
Nitrate	7.1	—	—	—	1	0.001
Nitrite	0.3	—	—	—	1	0.001
Selenium	0.005	—	—	—	1	0.001
Strontium	0.6	—	—	—	1	0.001
Tin	0.6	—	—	—	1	0.001
Tributyl phosphate	0.01	0.009	—	—	1	0.0228
Uranium	0.003	—	—	—	1	0.001

Source: RPP-ENV-58806, *RCRA Closure of Tank Waste Residuals Impacts at Waste Management Area C, Hanford Site Washington,* Rev. 1, Table 7-20.

[a] While no reference concentration values are available for this contaminant list, a value of 1×10^9 µg/m^3 was entered for each contaminant in GoldSim© to prevent divide by zero errors. Doing so results in exceedingly small values that have no impact on the final results.
[b] "—" indicates there is no value available for this chemical.

GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

REFERENCE

RPP-ENV-58806, in process, *RCRA Closure of Tank Waste Residuals Impacts at Waste Management Area C, Hanford Site, Washington*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.