RPP-CALC-60497, Rev. 0

Peak Groundwater Concentrations for Tank Farm 241-AX TWRWP Risk Assessment

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U.S. Department of Energy Contract DE-AC27-08RV14800

EDT/ECN: DRCF UC:
Cost Center: Charge Code:
B&R Code: Total Pages: 214

Key Words: Tank Waste Retrieval, Tank Waste Retrieval Work Plan, WMA A/AX, A Farm, AX Farm, Risk Assessment, Hanford Site, 200 East Area, Environmental Model Calculation File, STOMP, radioactive waste, tank residuals, tank waste retrieval, flow and contaminant transport, single-shell tanks

Abstract: This Environmental Model Calculation File (EMCF) documents modeling calculations performed to provide long-term human health risk information to support decisions in the event a leak is detected during waste retrieval operations at the 241-AX Tank Farm (AX Farm). A Tank Waste Retrieval Work Plan (TWRWP) will be prepared for each of four single-shell tanks in the AX Farm prior to retrieving interim stabilized nuclear waste from the tanks for offsite treatment and disposal. Each TWRWP includes a risk assessment which reports results of calculations in this EMCF and a companion EMCF (RPP-CALC-60498, "Tank Waste Pre Retrieval Assessment of Dose and Risk") of groundwater impacts from a hypothetical retrieval leak for the tanks and from other past and potential future releases from the tanks and equipment in Waste Management Area A/AX.

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APPROVED
By Julia Raymer at 9:27 am, Sep 25, 2015

Release Approval Date

DATE:
Sep 25, 2015
HANFORD RELEASE

Release Stamp

Approved For Public Release

ENVIRONMENTAL MODEL CALCULATION COVER PAGE

Section 1: Completed by Responsible Manager

RELEASE/ISSUE

Project: Waste Management Area A-AX Performance Assessment

Date: 09/10/2015

Calculation Title & Description: Peak Groundwater Concentrations for Tank Farm 241-AX TWRWP Risk Assessment

Section 2: Completed by Preparer

Calculation No.: RPP-CALC-60497 Revision No.: 0

Revision History

Revision No.	Description	Date	Affected Pages
0	Initial issue	09/25/2015	All

Section 3: Completed by Responsible Manager

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)

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A-6006-716 (REV 0)

Checker Log For Process Model
Model Parmeterization

Model parameter type	Input documeted in EMCF?	Values checked against parameter source?	Input in EMCF matches model input files?
Simulation duration: historic	JJ	NA	JJ
Simulation duration: predictive	JJ	NA	JJ
Boundary conditions: recharge	JJ	JJ	JJ
Boundary conditions: river	NA	NA	NA
Boundary conditions: head	JJ	JJ	JJ
Boundary conditions: specified flux	JJ	JJ	JJ
Initial conditions: hydraulic	JJ	NA	JJ
Initial conditions: contaminants present	NA	NA	NA
Initial conditions: contaminant amount	NA	NA	NA
Sources & sinks: aqueous mass	JJ	JJ	JJ
Sources & sinks: contaminant mass	JJ	JJ	JJ
Hydraulic properties: conductivity	JJ	JJ	JJ
Hydraulic properties: porosity	JJ	JJ	JJ
Hydraulic properties: water retention (vadose only)	JJ	JJ	JJ
Hydraulic properties: Particle density	JJ	JJ	JJ
Hydraulic properties: formation density	NA	NA	NA
Transport properties: diffusion	JJ	JJ	JJ
Transport properties: dispersivity	JJ	JJ	JJ
Transport properties: sorption (typically Kd)	JJ	JJ	JJ
Transport properties: radioactive decay rate	JJ	JJ	JJ

JJ = Checked by Justin Jayne
NA = Not Applicable

Checker Log For Process Model

Miscellaneous Calculations and Processes

Calculation/Process	Documeted in EMCF?	Checked against source?	EMCF matches model input files?
Identify indicator contaminants by calculating risk contrbution	JJ	JJ	JJ
Indicator contaminant source terms:			
Verify EIS source terms	JJ	JJ	JJ
Calculate stoichiometric speciation of nitrate/nitrite	JJ	JJ	JJ
Calculate unit source term spatial component	JJ	JJ	JJ
Calculate unit source term temporal component	JJ	JJ	JJ
Calculate elevations:			
Top of tank wrt grade	JJ	JJ	JJ
Bottom of tank wrt grade	JJ	JJ	JJ
Water table wrt grade	JJ	JJ	JJ
Calculate aquifer hydraulics:			
Effective hydraulic conductivity (K_{eff})	JJ	JJ	JJ
Hydraulic head gradient magnitude	JJ	JJ	JJ
Hydraulic head gradient direction	JJ	JJ	JJ
Specific discharge	JJ	JJ	JJ
Calculate diffusivity of nitrite	JJ	JJ	JJ
Re-run model to verify model output	NA	JJ	NA
Model output post-processing:			
Verify Perl script functionality	JJ	JJ	JJ
Verify Fortran executable functionality	JJ	JJ	JJ
Verify Microsoft Excel® spreadsheet functionality	JJ	JJ	JJ
Verify Results tables consistent with model output	JJ	JJ	JJ

JJ = Checked by Justin Jayne

NA = Not Applicable

CONTENTS

1.0 PURPOSE 1-1

2.0 BACKGROUND 2-1

2.1 SITE FEATURES 2-1

2.2 HYDROGEOLOGIC SETTING 2-1

2.3 CONSENT DECREE REQUIREMENTS AND RATIONALE FOR METHODOLOGY 2-5

2.3.1 Available Analyses of Saturated Zone 2-7

2.3.2 Waste Management Alternative 2B Features Relevant to Modeling 2-9

2.3.3 Available Analyses of Contaminant Inventory and Source Release Terms 2-10

2.3.4 Available Analyses to Identify Primary Indicator Contaminants 2-11

3.0 METHODOLOGY 3-1

3.1 DETERMINE PRIMARY INDICATOR CONTAMINANTS 3-1

3.2 COMPILE RELEVANT STOMP© INPUT FILES FROM TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT 3-2

3.3 SELECT CURRENT BUILD OF STOMP© AND ADJUST INPUT FILES FOR CONSISTENCY WITH TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT 3-3

3.4 LOCATE VERTICAL REFERENCE POINTS FOR STOMP© MODEL GRIDS 3-4

3.5 EXTEND STOMP© MODEL GRIDS FOR EACH TANK FARM DOWNWARD INTO SATURATED ZONE 3-5

3.6 ASSIGN AQUIFER PARAMETERS 3-5

3.7 ASSIGN BOUNDARY CONDITIONS AND INITIAL CONDITIONS 3-10

3.8 MODIFY TIME-STEPPING TO ACCOMMODATE SATURATED ZONE ADVECTION 3-14

3.9 ASSIGN ANY TRANSPORT PARAMETERS FOR INDICATOR CONTAMINANTS NOT SPECIFIED IN THE TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT 3-14

3.10 POPULATE SOURCE RELEASE TERMS OF INDICATOR CONTAMINANT INVENTORIES AND VOLUMES 3-16

3.10.1 Past Releases 3-16

3.10.2 Retrieval Leaks 3-17

3.10.3 Tank Residuals 3-18

3.10.4 Ancillary Equipment Residuals 3-18

3.11 SPECIFY OUTPUT OF FENCE LINE WATER AND SOLUTE FLUXES ACROSS SURFACES FOR REPORTING IN THE SURFACE FLUX CARD 3-18

3.12 RUN HISTORICAL SIMULATIONS IN STOMP© MODELS TO OBTAIN INITIAL CONDITIONS FOR CALENDAR YEAR 1940 AND CONFIRM STEADY STATE MOISTURE CONDITIONS 3-19

3.13 RUN PREDICTIVE SIMULATIONS IN STOMP© MODELS TO OBTAIN FENCE LINE WATER AND SOLUTE FLUXES 3-19

3.14 CONVERT FENCE LINE WATER AND SOLUTE FLUXES TO FENCE LINE GROUNDWATER CONCENTRATIONS AND DETERMINE THE TIME AND LOCATION OF PEAK IMPACT OF EACH INDICATOR CONTAMINANT FOR EACH SIMULATION 3-20

4.0 ASSUMPTIONS AND INPUTS 4-1

5.0 SOFTWARE APPLICATIONS 5-1

5.1 EXEMPT SOFTWARE 5-1

5.2 APPROVED SOFTWARE 5-1

5.2.1 STOMP© 5-1

5.2.2 MODFLOW and Related Codes Support Software 5-3

6.0 CALCULATION 6-1

6.1 DETERMINE PRIMARY INDICATOR CONTAMINANTS 6-1

6.2 COMPILE RELEVANT STOMP© INPUT FILES FROM TC&WM EIS 6-3

6.3 SELECT CURRENT BUILD OF STOMP© AND ADJUST INPUT FILES FOR CONSISTENCY WITH TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT 6-4

6.4 LOCATE VERTICAL REFERENCE POINTS FOR STOMP© MODEL GRIDS 6-4

6.5 EXTEND STOMP© MODEL GRIDS FOR EACH TANK FARM DOWNWARD INTO SATURATED ZONE 6-9

6.6 ASSIGN AQUIFER PARAMETERS 6-10

6.7 ASSIGN BOUNDARY CONDITIONS AND INITIAL CONDITIONS 6-11

6.8 MODIFY TIME-STEPPING TO ACCOMMODATE SATURATED ZONE ADVECTION 6-12

6.9 ASSIGN ANY TRANSPORT PARAMETERS FOR INDICATOR CONTAMINANTS NOT SPECIFIED IN THE TC&WM EIS 6-12

6.10 POPULATE SOURCE RELEASE TERMS OF INDICATOR CONTAMINANT INVENTORIES AND VOLUMES 6-13

6.10.1 Past Releases 6-13

6.10.2 Retrieval Leaks 6-13

6.10.3 Tank Residuals 6-13

6.10.4 Ancillary Equipment Residuals 6-13

6.11 SPECIFY OUTPUT OF FENCE LINE WATER AND SOLUTE FLUXES ACROSS SURFACES FOR REPORTING IN THE SURFACE FLUX CARD 6-13

6.12 RUN HISTORICAL SIMULATIONS IN STOMP© MODELS TO OBTAIN INITIAL CONDITIONS FOR CALENDAR YEAR 1940 AND CONFIRM STEADY STATE MOISTURE CONDITIONS 6-13

6.13 RUN PREDICTIVE SIMULATIONS IN STOMP© MODELS TO OBTAIN FENCE LINE WATER AND SOLUTE FLUXES 6-14

6.14 CONVERT FENCE LINE WATER AND SOLUTE FLUXES TO FENCE LINE GROUNDWATER CONCENTRATIONS AND DETERMINE THE TIME AND LOCATION OF PEAK IMPACT OF EACH INDICATOR CONTAMINANT FOR EACH SIMULATION 6-15

7.0 RESULTS/CONCLUSIONS 7-1

8.0 REFERENCES 8-1

ATTACHMENTS

1. CALCULATION OF SATURATED ZONE CONDITIONS FROM CPGWM Att-1-1
2. RE-CALCULATION OF NITRITE AND NITRATE SOURCE RELEASE TERMS ... Att-2-1
3. MATERIALS SUPPORTING ASSUMPTIONS AND INPUTS Att-3-1
4. SOFTWARE INSTALLATION AND CHECKOUT FORM Att-4-1

FIGURES

Figure 1. Location Map of the Hanford Site and Central Plateau Groundwater Model Extent. 2-2

Figure 2. Location Map of Waste Management Area A/AX. 2-3

Figure 3. Area of Waste Management Area A/AX with Tank Closure and Waste Management Environmental Impact Statement MODFLOW Grid and A Barrier Boundary. 2-8

Figure 4. Plan View Map of AX Farm STOMP© Model Horizontal Gridding. 3-3

Figure 5. Plan View Map of A Farm STOMP© Model Horizontal Gridding. 3-4

Figure 6. Area of Central Plateau Groundwater Model Corresponding to Tank Waste Retrieval Work Plan Model Domains. 3-8

Figure 7a. Hydraulic Conductivities of Central Plateau Groundwater Model Layers 2 and 3 Cells in Waste Management Area A/AX Region. 3-9

Figure 7b. Hydraulic Conductivities of Central Plateau Groundwater Model Layers 4 and 5 Cells in Waste Management Area A/AX Region. 3-10

Figure 7c. Hydraulic Conductivities of Central Plateau Groundwater Model Layers 6 and 7 Cells in Waste Management Area A/AX Region. 3-11

Figure 8. Central Plateau Groundwater Model Steady-State Flux in Layers 2 through 5 in Waste Management Area A/AX Region. 3-12

Figure 9a. First Example Comparison of Nearby Cross-Sections from Tank Closure and Waste Management Environmental Impact Statement STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment. 6-7

Figure 9b. Second Example Comparison of Nearby Cross-Sections from Tank Closure and Waste Management Environmental Impact Statement STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment. 6-8

Figure 9c. Third Example Comparison of Nearby Cross-Sections from Tank Closure and Waste Management Environmental Impact Statement STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment. 6-8

Figure 9d. Fourth Example Comparison of Nearby Cross-Sections from TC&WM EIS STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment. 6-9

Figure 10. Moisture Content at Selected Nodes of A Farm TWRWP Model Over Historical Simulation Period. 6-14

TABLES

Table 1a. Radionuclide Contributions to Peak Impacts at A Barrier Boundary from Tank Closure and Waste Management Environmental Impact Statement Alternative 2B Analysis. 6-1
Table 1b. Non-Radiological Chemicals Contributions to Peak Impacts at A Barrier Boundary from Tank Closure and Waste Management Environmental Impact Statement Alternative 2B Analysis. 6-2
Table 2. Unit Inventory Simulation Results for AX-101 Retrieval Leak Source Term. 7-4
Table 3. Unit Inventory Simulation Results for AX-102 Retrieval Leak Source Term. 7-5
Table 4. Unit Inventory Simulation Results for AX-103 Retrieval Leak Source Term. 7-5
Table 5. Unit Inventory Simulation Results for AX-104 Retrieval Leak Source Term. 7-6
Table 6. Tank AX-101 Retrieval Leak Inventory Estimate. 7-7
Table 7. Tank AX-102 Retrieval Leak Inventory Estimate. 7-7
Table 8. Tank AX-103 Retrieval Leak Inventory Estimate. 7-7
Table 9. Tank AX-104 Retrieval Leak Inventory Estimate. 7-8
Table 10. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from a Potential Retrieval Leak at Tank AX-101. 7-8
Table 11. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from a Potential Retrieval Leak at Tank AX-102. 7-9
Table 13. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from a Potential Retrieval Leak at Tank AX-104. 7-10
Table 14. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from Potential Retrieval Leaks at All A Farm Tanks. 7-10
Table 15. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from A Farm Past Releases. 7-11
Table 16. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from AX Farm Past Releases. 7-11
Table 17. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from All Past Releases. 7-12
Table 18. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from A Farm Tank Residuals. 7-13
Table 19. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from AX Farm Tank Residuals. 7-13
Table 20. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from All Tank Residuals. 7-14
Table 21. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from A Farm Ancillary Equipment Residuals. 7-15
Table 22. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from AX Farm Ancillary Equipment Residuals. 7-16
Table 23. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from All Ancillary Equipment Residuals. 7-16

TERMS

CPGWM	Central Plateau Groundwater Model
Consent Decree	Consent Decree in State of Washington v. Department of Energy, Case No. 08-5085-RMP (E.D. Wa. October 25, 2010)
DMT	Decision Management Tool
EMCF	Environmental Model Calculation File
HI	Hazard Index
HSU	Hydrostratigraphic Unit
HQ	Hazard Quotient
ILCR	Incremental Lifetime Cancer Risk
SST	Single-Shell Tank
TC&WM EIS	Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (DOE/EIS-0391)
TOB	Top of Basalt
TWRWP	Tank Waste Retrieval Work Plan
WMA	Waste Management Area

1.0 PURPOSE

This Environmental Model Calculation File (EMCF) documents contaminant fate and transport modeling calculations performed to provide long-term human health risk information to support operational decisions in the event a leak is detected during waste retrieval operations at the 241-AX Tank Farm (AX Farm). A Tank Waste Retrieval Work Plan (TWRWP) will be prepared for each of four underground single-shell tanks (SSTs) in the AX Farm prior to operations to retrieve interim stabilized nuclear waste from the tanks for offsite treatment and disposal. Each TWRWP includes a pre-retrieval risk assessment which reports results of calculations in this EMCF and a companion EMCF (RPP-CALC-60498, "Tank Waste Pre-Retrieval Assessment of Dose and Risk") of potential impacts to groundwater from a hypothetical retrieval leak for the tank in question and from other past and potential future releases from the tanks and equipment in Waste Management Area A/AX (WMA A/AX). The AX Farm and the 241-A Tank Farm (A Farm) comprise WMA A/AX.

The objective of the calculations in this EMCF is to determine the peak concentrations in groundwater at the WMA A/AX fence line from the simulated releases for a set of indicator contaminants expected to dominate the human health risk. RPP-CALC-60498 calculates human health risk metrics for the peak groundwater concentrations and also calculates radiological doses from residual tank waste for inadvertent human intrusion scenarios.

The requirement to consider long-term human health impacts in developing TWRWPs is described in Appendix C, Part 2, of the Consent Decree in State of Washington v. Department of Energy, Case No. 08-5085-RMP (E.D. Wa. October 25, 2010) (Consent Decree), and is detailed in Section 2. Consideration of alternative approaches to the calculations documented here, and rationale for the selected approach based on the Consent Decree requirements are described in Section 2.

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2.0 BACKGROUND

Section 2.1 discusses general site features of WMA A/AX. Section 2.2 discusses the hydrogeologic setting of WMA A/AX. Section 2.3 discusses requirements in the Consent Decree and other rationale for the overall methodology in this EMCF. Details of implementation using particular software are intended to assist internal quality assurance reviews by other users familiar with the software structure and syntax; other readers are referred to the cited user manuals.

2.1 SITE FEATURES

The AX Farm and A Farm are located in the 200 East Area of the Central Plateau of the Hanford Site (Figure 1). These two tank farms comprise WMA A/AX (Figure 2). The four underground SSTs in AX Farm include AX-101, AX-102, AX-103, and AX-104. The six underground SSTs in A Farm are numbered A-101 through A-106. Other documents may include a prefix "241-" before the name of each of these SSTs. Ancillary equipment including pipelines, catch tanks, diversion boxes, etc. is located (mostly buried) throughout WMA A/AX but concentrated around the SSTs.

A Farm was constructed between 1954 and 1955 and operations began in 1956; AX Farm was constructed between 1963 and 1964 and operations began in 1965 (RPP-ENV-37956, "Hanford 241-A/AX Farm Leak Inventory Assessment Report," p. 3-1; RPP-35484, "Field Investigation Report for Waste Management Areas C and A-AX," p. 6-8). The later construction dates compared to other Hanford SSTs are associated with some differences in design (including differences between A Farm and AX Farm), so for the respective tank farms the SSTs may be referenced collectively as the A-100-series tanks or the AX-100-series tanks (construction details are summarized in RPP-ENV-37956). A basic design difference affecting risk assessment calculations is that both the A-100-series and AX-100-series tanks have larger capacities resulting in deeper tank bases than other Hanford SSTs.

2.2 HYDROGEOLOGIC SETTING

A summary of current information regarding the hydrogeologic setting at WMA A/AX is provided in RPP-ENV-58578, "Summary of the Natural System at Waste Management Area A/AX." Only selected details from past investigations are presented here if referenced in the development of the calculations. The Hanford Site is underlain by the Miocene Columbia River Basalt Group. The gravel lying on basalt beneath much of the northern half of the 200 East Area has been variously interpreted as Ringold Formation unit A, as gravels deposited during Cold Creek time, or as part of the cataclysmic Hanford flood deposits that include some reworked Ringold. WMAs A/AX and C lie along the edge of a paleochannel that eroded much or all of the Ringold Formation during CCU and/or Hanford deposition time. Because of the difficulty in distinguishing reworked Ringold Formation gravels and pre-Missoula mainstream Columbia River gravels from original Ringold Formation gravels, these units are undifferentiated here (H3/CCU/R). The thickness of the uppermost aquifer generally increases from north to south as the top of basalt dips into the Cold Creek syncline.

Figure 1. Location Map of the Hanford Site and Central Plateau Groundwater Model Extent.

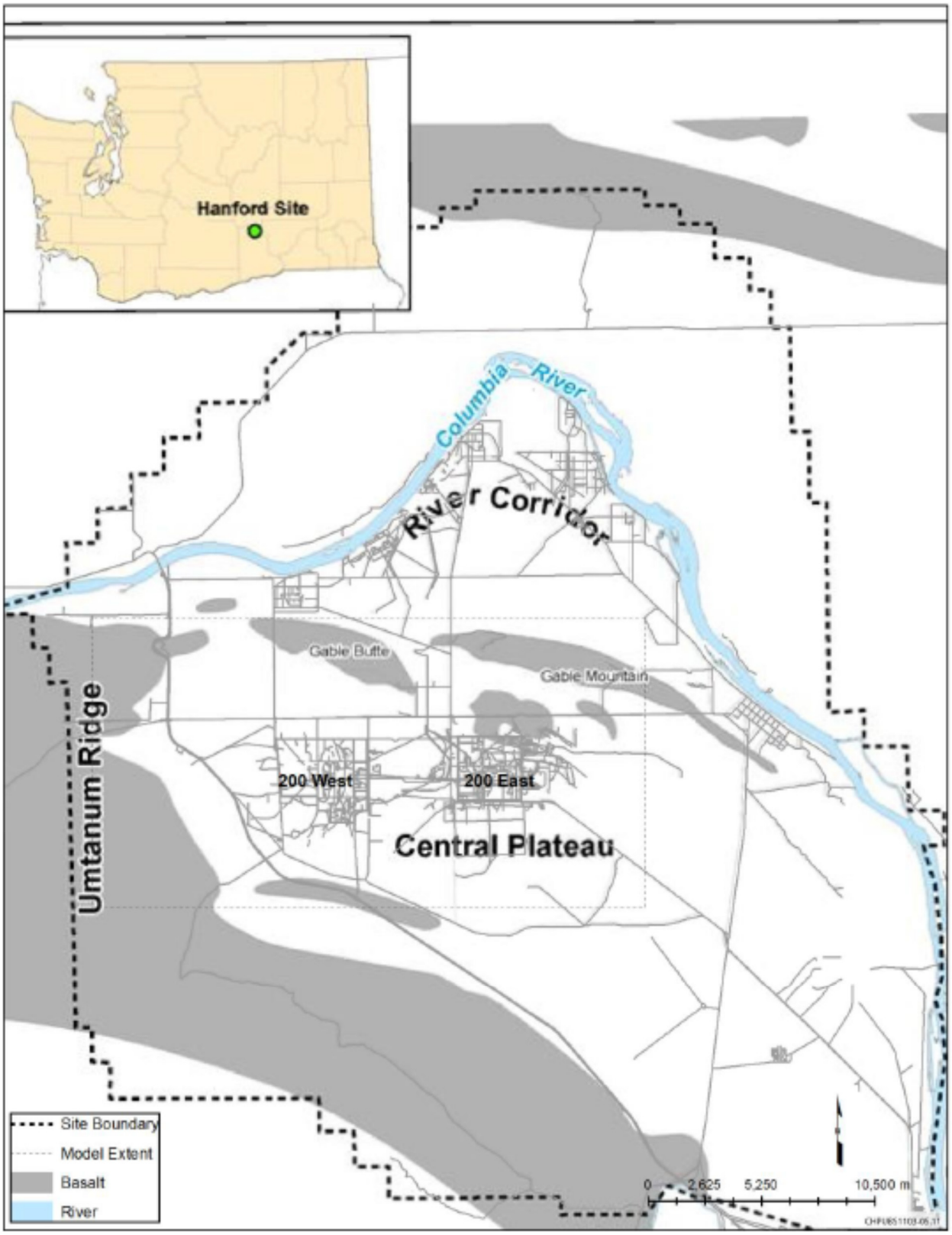
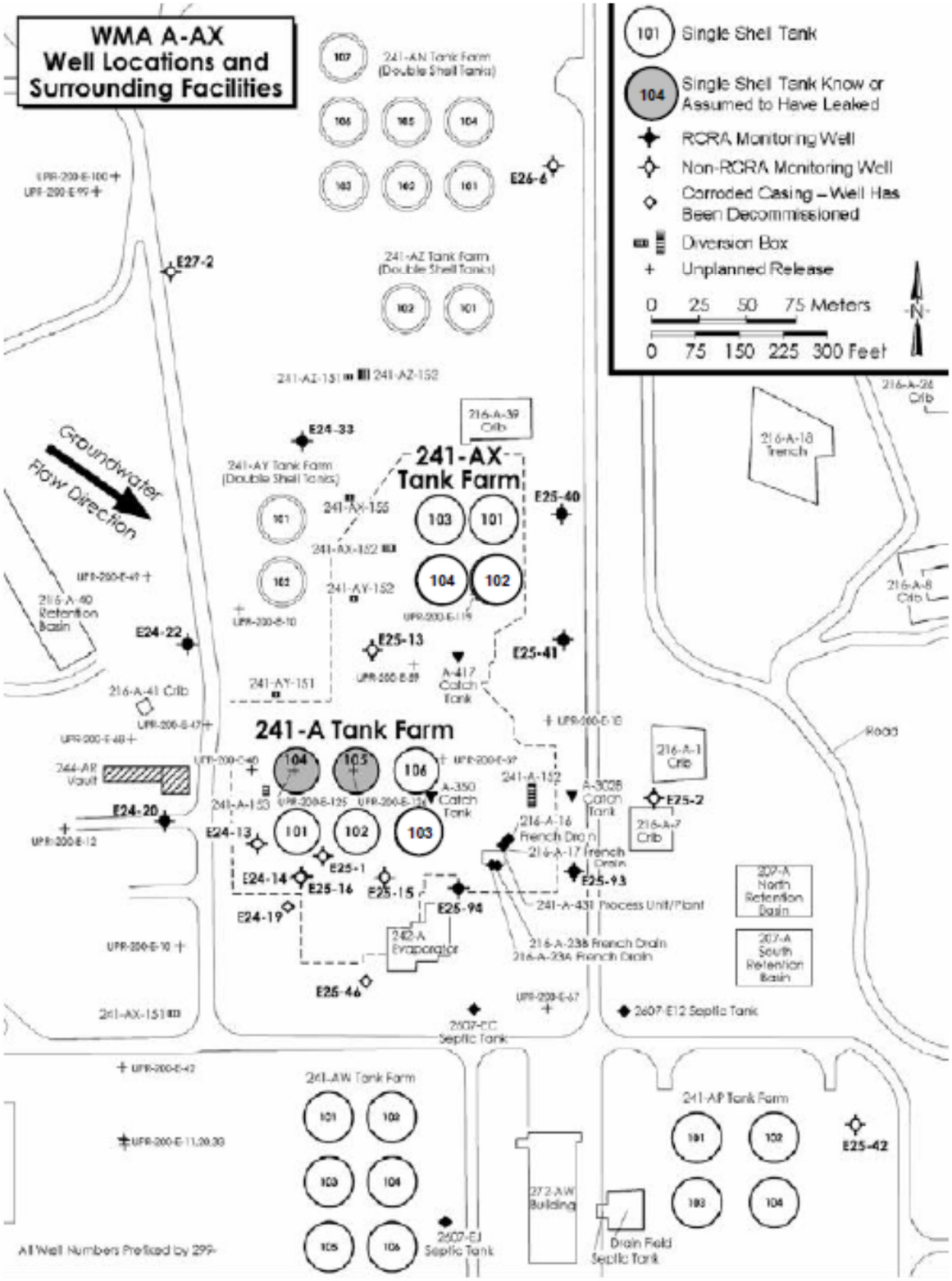


Figure 2. Location Map of Waste Management Area A/AX.



Note: Dashed lines show perceived WMA A-AX boundary (fence line).

RCRA = *Resource Conservation and Recovery Act of 1976* WMA = Waste Management Area

Past modeling analyses have conceptualized the unconsolidated sediments of the Hanford Formation based alternately on interpreted stratigraphic units (e.g., DOE/RL-2011-50, Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection) or on textural variation (e.g., DOE/EIS-0391, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington [TC&WM EIS]), providing different schemes by which to parameterize hydraulic properties. A fine-grained unit is found in most boreholes beneath WMA A/AX at a depth of about 79 m, with descriptions of the unit varying from clay or mud to sandy silt (RPP-ENV-58578, pp. 3-29).

Since the start of Hanford Site operations in the mid-1940s, artificial recharge from wastewater disposal facilities has caused an increase in the water table elevation over most of the Hanford Site including a rise of as much as 5 m in the vicinity of WMA A/AX (RPP-ENV-58578, pp. 5-1). Following the elimination of most site operations and most discharges, water levels have been declining since about the 1990s (RPP-ENV-58578, Figure 5-7; CP-47631, "Model Package Report, Central Plateau Groundwater Model, Version 6.3.3," Appendix A pp. A-12).

The gravels comprising the aquifer in the 200 East area have high hydraulic conductivities ranging from a few meters per day up to values beyond the limits of direct measurement, which in turn produce an extremely flat hydraulic gradient. The upper range of modeled hydraulic conductivities for the gravels extends to thousands or tens of thousands of meters per day (e.g., 3,982 m/d for the "Highly Conductive Hanford Formation" zone in DOE/EIS-0391, Table L-15; or 17,000 m/d for the "Hanford" unit in CP-47631, Table 4-9).

The lateral hydraulic gradient on the local scale of WMA A/AX is currently too small to measure given the accuracy of standard techniques; the estimate on the scale of the 200 East area is 1.8×10^{-5} toward the southeast, i.e., 1.8 cm per km (CHPRC-02485-VA, "Groundwater Flow Beneath Waste Management Area A-AX"; RPP-ENV-58578; SGW-54165, "Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site"). Even that value may be too high for the vicinity of WMA A/AX because the hydraulic gradient flattens out toward the southeast. The lower magnitude of the hydraulic gradient near WMA A/AX could also make the local flow direction sensitive to changes from external forces such as artificial discharges, groundwater extraction wells, and long-term changes to regional flow fields. RPP-ENV-58578 (pp.5-8) reports, "General groundwater flow directions and general flow rates are difficult to determine for the SST WMA A/AX due to the relatively flat water table beneath the 200 East Area," but, "groundwater flow has historically been to the southeast," and, "generally, the magnitude of the gradient in the area surrounding WMA A/AX is on the order of magnitude of 1E-5."

A recent analysis attempting to systematically minimize sources of error in 200 East hydraulic gradient measurements showed noteworthy improvement in the ability to provide credible mapping of the current water table elevation by applying gyroscopic survey corrections for well deviations from verticality to historical measurements, among other physically-based and statistical techniques (CHPRC-02485-VA, SGW-54165). The resulting water table maps could reasonably be considered the most sophisticated available analysis of the current hydraulic gradient in the vicinity of WMA A/AX. Drawbacks of using the resulting water table maps are that the approach to correcting the hydraulic heads (i.e. the particular combination of correction

methods) is relatively new and that limited historical Hanford Site data are reported with the same corrections, however future re-analysis of historical data is possible should it be necessary for other modeling efforts. Regarding future data collection, the success of these recent efforts has encouraged continuing collection of new data from a network of selected wells using similar quality control measures.

2.3 CONSENT DECREE REQUIREMENTS AND RATIONALE FOR METHODOLOGY

The Consent Decree, Appendix C, Part 2, Item 4, states the information provided in the work plans will include the following:

A pre-retrieval risk assessment of potential residuals, consideration of past leaks, and potential leaks during retrieval, based on available data and the most sophisticated analysis available at the time. The purpose of this risk assessment is to aid operational decisions during retrieval activities. This risk assessment will not be used to make final tank retrieval or closure decisions. The risk assessment will contain the following, as appropriate:

- Long-term human health risks associated with potential leaks during retrieval and potential residual waste after completion of retrieval:
    - Potential impacts to groundwater, including a WMA-level risk assessment
    - Potential impacts based on an intruder scenario
- Process management responses to a leak during retrieval and estimated potential leak volume
- The pre-retrieval risk analysis will be based on the following criteria:
    - Using the WMA fence line for point of compliance
    - Identify the primary indicator contaminants (accounting for at least 95% of impact to groundwater risk) and provide the incremental lifetime cancer risk (ILCR) and hazard index (HI)
    - Using ILCR and HI for the industrial and residential human scenarios as the risk metric
    - Calculated concentration(s) of primary indicator contaminant(s) in groundwater (mg/L, and pCi/L).

It should be noted that this pre-retrieval risk assessment is, by definition, much smaller in scope than a Performance Assessment (PA) as defined by DOE M 435.1-1, Radioactive Waste Management Manual. Requirements for a PA developed for WMA A/AX at a later date derive

from multiple regulatory authorities and involve more extensive evaluation of conceptual models, inputs, and assumptions. Parts of a PA, for example, could include the use of model sensitivity cases to compare alternative inputs or a system model to quantify the net effects of multiple parameter uncertainties. A PA uses an iterative process in which data gaps may be identified and filled by further data collection in support of model revisions. In contrast, the Consent Decree requirements for the pre-retrieval risk assessment recognize reliance on currently available data and analyses.

Contaminant fate and transport modeling, as opposed to alternative types of analyses, is effectively mandated by the Consent Decree requirements for the pre-retrieval assessment of long-term human health risk, i.e., the quoted section requires calculating contaminant concentrations in groundwater at the WMA fence line based on potential releases that could occur in the future. Rather than specify a particular modeling approach, the Consent Decree stipulates "the most sophisticated analysis available at the time," such that some degree of evolution in modeling approach may be anticipated as TWRWPs are prepared for different SSTs over time.

Past TWRWPs for SSTs in other waste management areas at the Hanford Site have applied the capabilities embodied in the Decision Management Tool (DMT) (see RPP-39234, "Decision Management Tool Version 5 User's Manual"). The underlying capabilities and results in the DMT are based on groundwater impact results developed from a two-dimensional cross-sectional fate and transport model to calculate groundwater concentrations used in DOE/ORP-2005-01, Initial Single-Shell Tank System Performance Assessment for the Hanford Site. The DMT methodology was considered for the present analysis as an alternative approach but, based on the following discussion, was determined not to be the most current site-specific tool available.

The methodology developed in this EMCF is largely based on local-scale modeling tools for the A Farm and AX Farm more recently developed to support DOE/EIS-0391 (TC&WM EIS) with some modification. The methodology uses three-dimensional models in the most current approved build of the Subsurface Transport Over Multiple Phases (STOMP)©* simulator (PNNL-15782, "STOMP, Subsurface Transport Over Multiple Phases, Version 4.0, User's Guide") to simulate contaminant transport through the vadose zone and the upper region of the aquifer. The TC&WM EIS model simulations relevant to WMA A/AX included each of the types of releases required to be considered in the TWRWP (past leaks, potential retrieval leaks, and potential releases from residuals). The use of modeling tools from the TC&WM EIS, with the few modifications necessary for the TWRWP, is more sophisticated than the DMT approach in the sense that it explicitly models flow and transport in three dimensions rather than two dimensions, and it provides a parameterization that was prepared at a later date and thus able to incorporate additional information that became available after the DMT was prepared. Another anticipated advantage of the TC&WM EIS modeling tools is relatively strong regulatory acceptance given the multi-year public process of reviews and input involved in the approval of the TC&WM EIS. Use of STOMP© for vadose zone modeling applications related to groundwater protection at the Hanford Site, and specifically use of the TC&WM EIS parameterization for initial values, are guiding principles of the Graded Approach endorsed by

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

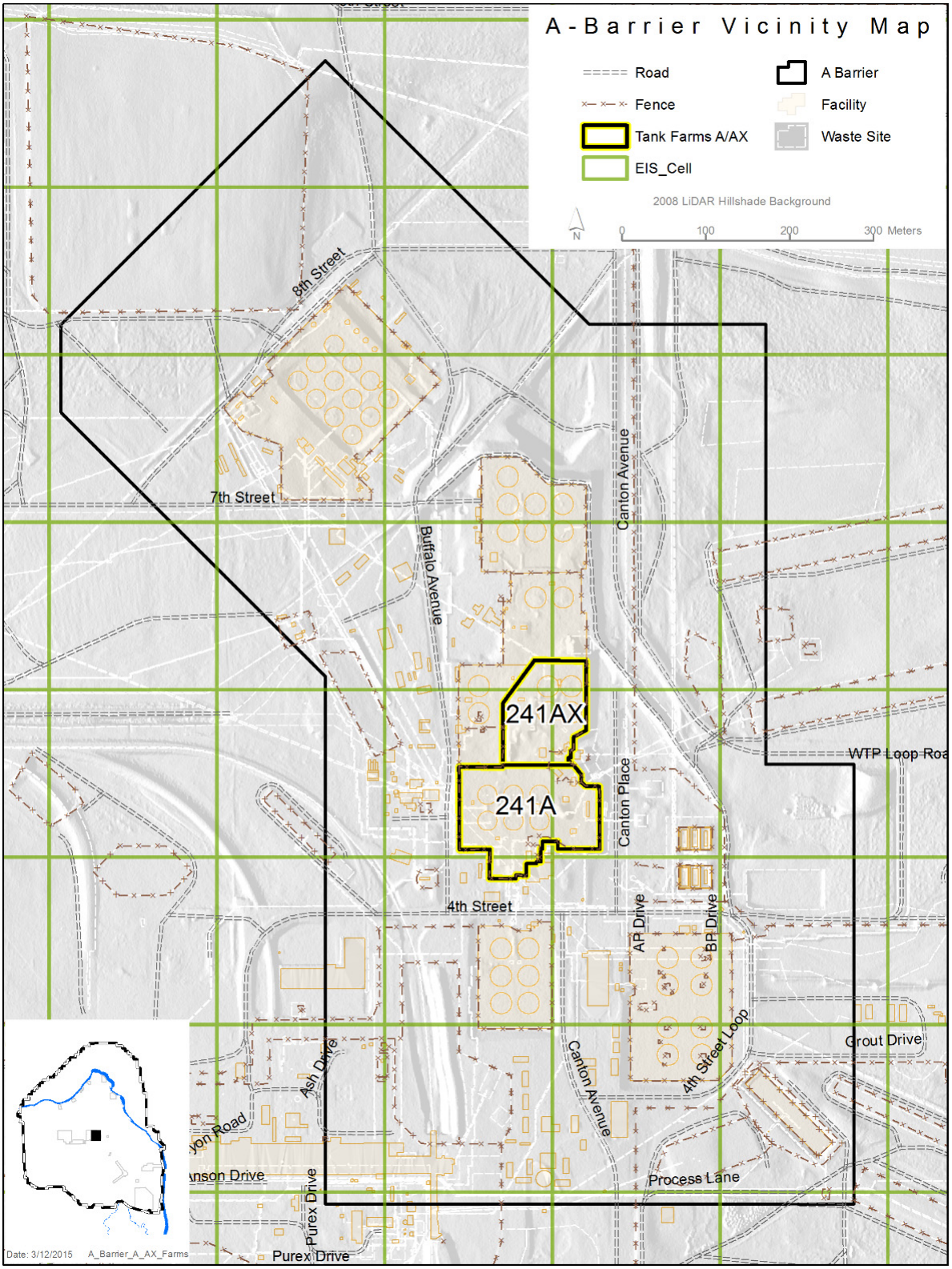
federal and state regulators in the slightly different, but analogous, context of determining preliminary remediation goals for vadose zone soil (DOE/RL-2011-50). DOE/RL-2011-50 further elaborates on the rationale supporting use of these tools for calculations of this type at the Hanford Site.

2.3.1 Available Analyses of Saturated Zone

Unlike the TC&WM EIS vadose zone flow and transport implementation, the TC&WM EIS model implementation of saturated zone flow and transport is not directly applicable to the TWRWP objectives. In particular, it cannot provide groundwater concentrations at the WMA A/AX fence line without substantial modifications to the existing discretization and to the code used to transfer mass from the vadose zone models to the saturated zone model. The TC&WM EIS evaluated Hanford site-wide cumulative impacts of sources, including those in WMA A/AX and numerous other source areas, to provide a basis to decide between waste management alternatives for the Hanford Site as a whole. To do this, the TC&WM EIS model implementation involved individual, local-scale site models of vadose zone transport for each tank farm or other area of concern, and a regional-scale (Hanford site-wide) set of models for saturated zone flow and transport. Saturated zone flow was implemented in MODFLOW-2000 (USGS Open-File Report 00-92, "MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model—User Guide to Modularization Concepts and the Ground-Water Flow Process") and saturated zone transport was implemented in a custom-built FORTRAN code called Blue Dot (the particle tracking simulations are described in DOE/EIS-0391 Appendix O). The STOMP© models of the vadose zone at the A Farm and the AX Farm from the TC&WM EIS are well-suited to the local scale required for the TWRWP calculations, whereas the regional saturated zone flow and transport models are not suited for local-scale simulations to determine groundwater concentrations at the fence line. For example, the MODFLOW grid used 200-m × 200-m cells to calculate the regional flow field (cells are outlined in green in Figure 3), whereas the lateral transport distance between the WMA A/AX tanks and the fence line is as little as 10 m (Figure 2). STOMP© is capable of simulating both unsaturated and saturated flow regions in a single model, so a logical method to adapt the TC&WM EIS model to meet the TWRWP objectives is to extend the STOMP© model domains into the saturated zone (providing discretization fine enough to follow the fence line) and parameterize the STOMP© saturated zone based on the most sophisticated analysis of the aquifer conditions currently available.

Alternatives for determining applicable aquifer conditions include the TC&WM EIS MODFLOW model and the Central Plateau Groundwater Model (CPGWM) (CP-47631). Both models have a similar framework, that is, both are Hanford Site flow models implemented in MODFLOW-2000 for regions much broader than WMA A/AX with similar conceptual models and parameterizations. As explained in the discussion that follows, because the current calibration of the CPGWM, calibration Version 3.3 described in CP-47631, represents a more recent analysis incorporating various incremental refinements not available when the TC&WM EIS model was developed, the CPGWM is interpreted to be the most sophisticated analysis of the aquifer conditions currently available.

Figure 3. Area of Waste Management Area A/AX with Tank Closure and Waste Management Environmental Impact Statement MODFLOW Grid and A Barrier Boundary.



Initial development of the CPGWM as a modification of a model for the 200-ZP-1 Operable Unit began around 2009, the same year a draft version of the TC&WM EIS was released. Subsequently, the domain of the CPGWM was enlarged to cover the Central Plateau region of the Hanford Site (Figure 1) using 100-m × 100-m cells (a factor of 4 increase in discretization versus the TC&WM EIS groundwater flow model). The final TC&WM EIS released in 2012 lists changes made to the TC&WM EIS model since the draft (section L.1.6 in Appendix L, DOE/EIS-0391), and they do not include some important refinements implemented in the CPGWM since 2009. Refinements were made to the CPGWM model stratigraphy based on re-evaluation of old and new boring logs and new seismic data, and multiple iterations of model versions and model calibrations were completed to improve fits to current and pre-Hanford hydraulic heads (CP-47631). Current head data used in CPGWM, calibration Version 3.3, include observed heads in several wells in the vicinity of WMA A/AX. Sensitivity analysis in the TC&WM EIS revealed that, depending on the top of basalt (TOB) bedrock surface elevation in the Gable Mountain-Gable Butte area (Figure 1), two alternative regional flow fields fit the calibration data equally well yet diverge in the post-Hanford period, with consequences for predicted groundwater impacts (see sections O.6.1 and O.6.2 in Appendix O, DOE/EIS-0391). Although the CPGWM documentation still describes uncertainty regarding the elevation of the basalt ridge as an overall model limitation, the successive CPGWM versions have made progress relative to the TC&WM EIS in addressing that uncertainty through such measures as using new seismic data to revise the TOB surface (CP-47631). Note that the CPGWM uses a variant of MODFLOW-2000, denoted by "MST," that includes source code modifications to deal with minimum saturated thickness issues, that was developed as part of the 200-ZP-1 Operable Unit groundwater modeling work (CHPRC-00258, "MODFLOW and Related Codes Software Management Plan"). An example of an application of the CPGWM for decision-making subject to regulatory oversight is DOE/RL-2008-78 Draft A, 200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan. Additional specific CPGWM applications are listed in Section 7.2 of the Model Package Report (CP-47631).

2.3.2 Waste Management Alternative 2B Features Relevant to Modeling

The outcome of the TC&WM EIS analysis of waste management alternatives included the selection of Alternative 2B for the long-term management of tank waste. Alternative 2B defines various details of future operations that effectively specify a common set of parameter values for subsequent calculations. These include retrieval of 99% of current tank farm SST waste inventories and a proportional amount of waste inventory in ancillary equipment for treatment and disposal, grouting of residual tank waste in place, and construction of a surface barrier over closed SSTs to minimize infiltration.

For purposes of this analysis and others cited, the surface barrier design (e.g., its component materials and thickness) is not specified; rather it is assigned performance objectives based on completed research, including a maximum infiltration rate. As a result of the unknown design, the STOMP© model domains have upper boundaries near the present day ground surface that exclude the barrier itself and instead invoke boundary conditions that represent its effect on infiltration rates into the shallow sediments above the top of the waste. The TC&WM EIS modeling of Alternative 2B scenarios assumed placement of the surface barrier at a final tank farm closure date of 2050, followed by barrier performance at design objectives until degradation

of the barrier 500 years later. In the STOMP© input files these assumptions are reflected directly in infiltration rates as well as indirectly in the source release terms discussed next in Section 2.3.3.

2.3.3 Available Analyses of Contaminant Inventory and Source Release Terms

The existing TC&WM EIS STOMP©-based models incorporate source release terms representing each of the types of releases required to be considered in the TWRWP (past leaks, potential retrieval leaks, and potential releases from residuals), using a different input file to separately simulate each type of release for each tank farm. Potential releases from residuals were further divided into simulations for residuals in tanks and simulations for residuals in ancillary equipment associated with the tanks. Finally, for each type of release, separate input files were used for simulations of a group of radiological contaminants and a group of non-radiological chemical contaminants, where the model inputs were identical except for contaminant-specific parameters and inventories. Inventory is the term used in modeling at the Hanford Site for the total amount of each contaminant estimated for each release. The TC&WM EIS used a custom-built FORTRAN code referred to as the "Release to Vadose Zone" code to simulate releases of contaminants from waste and to output source terms in STOMP© format as input to the vadose zone transport simulations (see DOE/EIS-0391 Appendix M for a full discussion of the mathematical models included). Thus, inventories were represented in this case by a series of release rates applied over successive, defined time intervals in the source terms in the STOMP© input files, such that it is not necessary to re-run the release to vadose zone code to simulate the same or substantially similar releases.

Between the types of source terms included in the pre-retrieval risk assessment, the most effort toward updating implementation was focused on potential retrieval leaks given the Consent Decree statement that, "The purpose of this risk assessment is to aid operational decisions during retrieval activities." Source terms for past releases and waste residuals are understood to generally provide context for the assessment of potential retrieval leaks as part of the "WMA-level risk assessment," so they are implemented in substantially the same manner as in the TC&WM EIS, which is interpreted for this purpose to be "the most sophisticated analysis available at the time."

At the time of undertaking a pre-retrieval risk assessment, interpreting the TC&WM EIS or any other analysis as the most sophisticated available for sources other than retrieval leaks unavoidably involves a certain amount of professional judgment, because generation of new data that offers a potential basis to refine inventories or release models is a more or less continuous process until final closure. For example, field observations impacting the interpreted nature, extent, timing, or location of some individual past release or the concentration of individual contaminants within a past release may be published between the date of the last WMA-level analysis and the final date of the TWRWP, but it may not be practical to evaluate every such change within a finite timeframe for modeling, documentation, and quality assurance. A longer timeframe and more appropriate resources for such an evaluation are allotted in other contexts such as performance assessments. To minimize the influence of a few individuals' judgment, reference is made to the Graded Approach in general and to current guidance recommending that similar calculations default to the TC&WM EIS for initial values in particular (DOE/RL-2011-50, Rev. 1).

Inventories developed from thermodynamic modeling using the OLI Systems Inc. Stream Analyzer (RPP-RPT-58867, "AX Farm Groundwater Risk Constituent Concentration Determination") represent the most sophisticated analysis available for the AX Farm tank retrieval leaks. Concentrations of contaminants were modeled taking into account the nature of waste present in individual tanks and the contaminants' speciation and solubility in water of high ionic strength over a range of temperatures when water is used in incremental volumes to sluice waste for retrieval. In the event that water leaks during retrieval, the potential concentrations can be multiplied by the hypothetical leak volume to obtain contaminant inventories. Changes in assumptions such as the leak volume may result in lower or higher inventories, so contaminant transport simulations based on unit inventories provide flexibility by calculating groundwater impacts that can be scaled to the independent leak inventory estimates.

In lieu of thermodynamic modeling results, the A Farm tank retrieval leaks retain the inventory assumptions used in the TC&WM EIS which involve simple dilution (DOE/EIS-0391 Appendix D). The TC&WM EIS used a single source term for retrieval leaks from all six tanks in the A Farm occurring simultaneously. The A Farm tanks are expected to be retrieved in accordance with a future TWRWP(s) in which assumptions may be updated (for instance, tanks A-104 and A-105 are unlikely to be sluiced in light of past leaks). Pending that assessment, the TC&WM EIS assumptions for the A Farm potential retrieval leaks source term are retained as the most sophisticated analysis available for the A Farm at this time.

Prior to retrieval operations beginning, the Alternative 2B objective of retrieving at least the specified fractions of current waste inventories provides the basis for calculating residual source terms. Note that following retrieval operations, additional information including laboratory analysis of samples of residual waste is generated that provides a basis to recalculate source terms for post-retrieval risk assessments.

The Consent Decree requirement for a WMA-level risk assessment can be satisfied by including these source terms for both the AX Farm and the A Farm. The AX Farm model grid is centered on the SSTs in the AX Farm and has its maximum resolution (finest discretization) near the SSTs and the portion of the fence line closest to the SSTs. The A Farm model grid overlaps the AX Farm model grid but is centered on the SSTs in the A Farm and uses a different discretization that has maximum resolution near the A Farm SSTs and the portion of the fence line closest to them. The implications of this approach inherited from the TC&WM EIS are that source terms for each tank farm are simulated separately using different input files with different grids, and that calculations at the fence line use different discretizations of the fence line as appropriate for the given simulation.

2.3.4 Available Analyses to Identify Primary Indicator Contaminants

Results of the existing TC&WM EIS model and the DMT both inform the selection of indicator contaminants to account for 95% of the ILCR and HI metrics. Tables Q-69, Q-92, Q-100, and Q-108 in Appendix Q of the TC&WM EIS (DOE/EIS-0391) provided contaminant-specific impact contributions under Alternative 2B at the "A Barrier Boundary" for each source term for multiple groundwater exposure scenarios. For the limited purpose of supporting a rational selection of indicator contaminants, the "Drinking-Water Well User" and "Resident Farmer" exposure scenarios are deemed reasonably similar to the industrial and residential human

scenarios specified by the Consent Decree based on similar receptors and exposure pathways involving drinking water and/or crop irrigation (see DOE/EIS-0391, RPP-CALC-60498, and HNF-SD-WM-TI-707, "Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments" for scenario details). The A Barrier Boundary is a hypothetical line of analysis encompassing an area much larger than WMA A/AX and including multiple other source areas (Figure 3). The TC&WM EIS evaluated a broad list of contaminants via screening and modeling and predicted most of them would not be significant for any source within the A Barrier Boundary. DOE/EIS-0391 Appendix Q, page Q-35 states, "only those radioactive and chemical constituents that resulted in a lifetime risk or Hazard Index greater than 1×10^{-10} for all impacts analysis locations for a given source are included in the human health impact tables presented in this section." The remaining contaminants shown in the Appendix Q tables included ^{99}Tc, ^{129}I, tritium, chromium, nitrate, and acetonitrile (tritium and acetonitrile contributions were minor). Note that chromium was assumed to exist entirely as the most mobile and most toxic species, hexavalent chromium, in lieu of analysis to the contrary. Because impacts were many orders of magnitude greater than 10^{-10} for the dominant contaminants, it is inferred that no other contaminants are required to account for 95% of ILCR and HI for WMA A/AX source terms at the WMA fence line at the time of peak impact within the 10,000-year period of analysis. Analysis using the DMT offers a means of checking this finding. Note the TC&WM EIS model showed uranium dominating radiological and chemical impacts and increasing concentration at the end of the 10,000 years, but the impacts at that time were less than the earlier peak impacts from more mobile constituents.

Previous TWRWP analysis for selected tanks in WMA C (RPP-22393, "241-C-102, 241-C-104, 241-C-107, 241-C-108, and 241-C-112 Tanks Waste Retrieval Work Plan") confirmed prediction of a similar list of dominant contaminants for WMA C source terms: ^{99}Tc, chromium, and nitrite. WMA C is northwest of WMA A/AX in the shaded area between 7th Street and 8th Street on Figure 3. The basis of DMT capabilities results were developed in DOE/ORP-2005-01, which evaluated fence line concentrations for the several WMAs that include SSTs (including WMA A/X). From this analysis, a general list of six indicator contaminants was selected "to illustrate a range of mobility and because they are primary risk drivers" (pp. 4-3): ^{99}Tc, hexavalent chromium, ^{129}I, nitrate, nitrite, and uranium. The DMT results are not relied upon directly; rather they are interpreted as supporting the use of the indicators identified from the TC&WM EIS analysis, with the exception that they also merit further consideration of assumptions about nitrite and nitrate in the local-scale TWRWP calculations.

One difference between the TC&WM EIS and previous assessment tools such as DMT is the assumption in the TC&WM EIS that nitrite inventory for all source terms would be converted to nitrate prior to transport to the point of calculation. Thus, the TC&WM EIS model did not specifically evaluate nitrite independently and its results identified nitrate as a significant hazard contributor, whereas previous assessments of tank farm sources routinely identified nitrite as a significant hazard contributor and not necessarily nitrate. Because analyzing the validity of the assumption for all relevant source terms is non-trivial, and because nitrite has higher toxicity than nitrate, the TWRWP analysis recalculated source terms to separately simulate both nitrite and nitrate. The separate results allow consideration of a broader range of potential leak inventories, since impacts of each contaminant can be scaled to different inventory assumptions (from zero to arbitrarily large values) corresponding to assumptions about oxidation-reduction conditions, kinetics of reactions, or other factors.

3.0 METHODOLOGY

The following steps were followed to perform the calculations:

1. Determine primary indicator contaminants
2. Compile relevant STOMP© input files from TC&WM EIS
3. Select current build of STOMP© and adjust input files for consistency with TC&WM EIS
4. Locate vertical reference points for STOMP© model grids
5. Extend STOMP© model grids for each tank farm downward into saturated zone
6. Assign aquifer parameters
7. Assign boundary conditions and initial conditions
8. Modify time-stepping to accommodate saturated zone advection
9. Assign any transport parameters for indicator contaminants not specified in the TC&WM EIS
10. Populate source term releases of indicator contaminant inventories and volumes
11. Specify output of fence line water and solute fluxes across surfaces for reporting in the Surface Flux Card
12. Run historical simulations in STOMP© models to obtain initial conditions for calendar year 1940 and confirm steady state moisture conditions
13. Run predictive simulations in STOMP© models to obtain fence line water and solute fluxes
14. Convert fence line water and solute fluxes to fence line groundwater concentrations and determine the time and location of peak impact of each indicator contaminant for each simulation.

Methodology for each step is discussed in the following subsections, and a corresponding subsection of Section 6 details the performance of each step.

3.1 DETERMINE PRIMARY INDICATOR CONTAMINANTS

The primary human health impact metrics calculated in the companion EMCF (RPP-CALC-60498) for which indicator contaminants are identified as part of this EMCF were

radiological ILCR and noncarcinogenic chemical HI (HI is defined as the sum of individual chemical hazard quotients, or HQs). Nonradiological ILCR was also included for information purposes. Indicator contaminants estimated to account for at least 95% of impact to groundwater risk for each human health impact metric were identified based on the results of the TC&WM EIS as well as the DMT.

Tables Q-69, Q-92, Q-100, and Q-108 in Appendix Q of DOE/EIS-0391 provided contaminant-specific impact contributions under Alternative 2B at the A Barrier Boundary for each source term for the "Drinking-Water Well User" and "Resident Farmer" exposure scenarios. Percentage contributions were determined by dividing the value of each health metric for each contaminant by the total value. The indicator contaminants accounting for at least 95% of impacts over the range of source terms and exposure scenarios were technetium-99 (^{99}Tc), iodine-129 (^{129}I), chromium, and nitrate. Nitrite was retained in addition to nitrate because the DMT indicated a sensitivity to the nitrogen speciation assumption in the TC&WM EIS, and evaluating the assumption is non-trivial.

Limited preliminary runs of the TWRWP models adapted from the TC&WM EIS models for this EMCF included a range of contaminants to provide confirmation that non-indicator contaminants either did not arrive at the point of analysis or had groundwater concentrations less than those of the indicator contaminants over the 10,000-year simulation period.

3.2 COMPILE RELEVANT STOMP© INPUT FILES FROM TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT

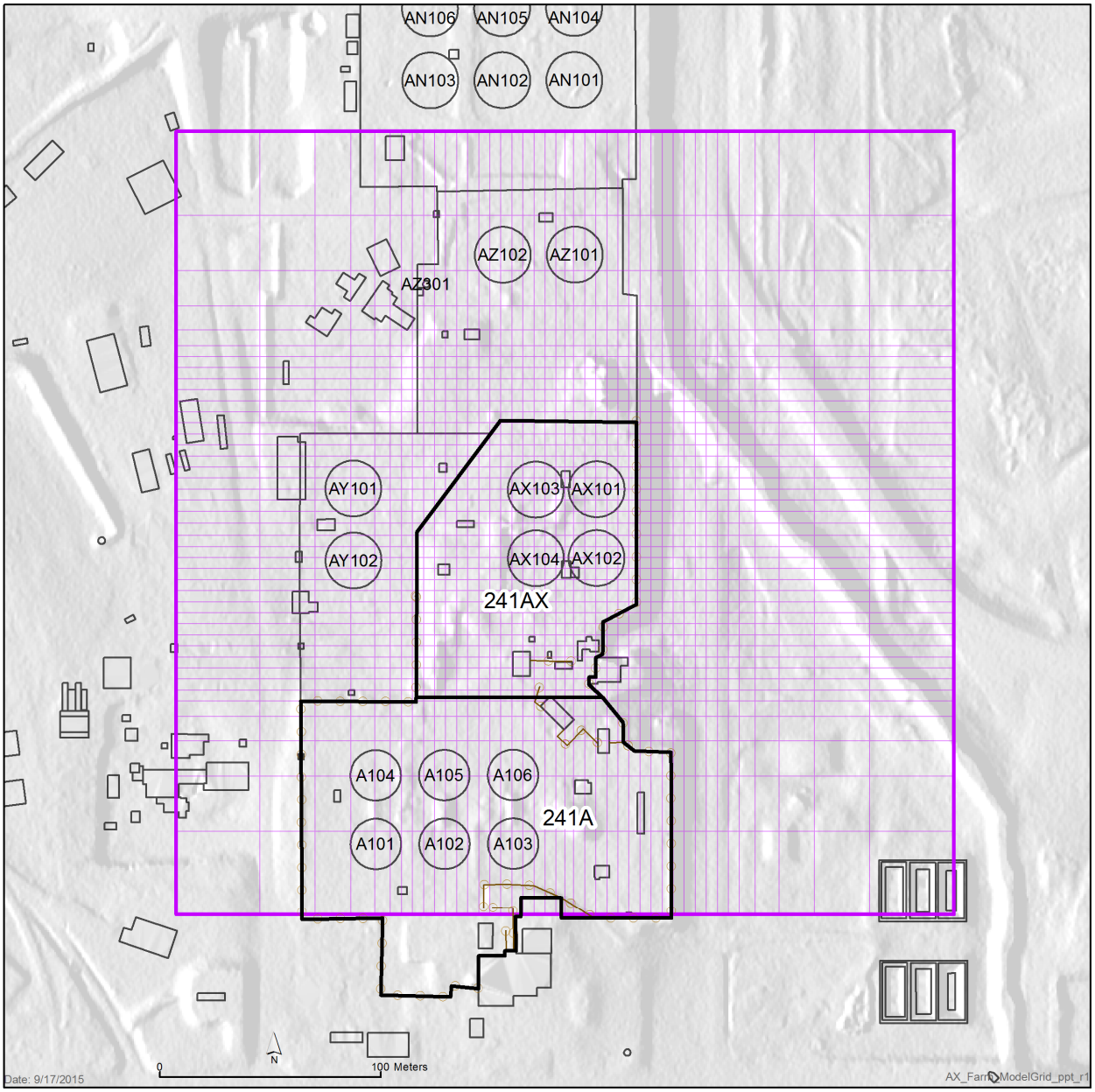
The TC&WM EIS STOMP© models used separate simulation input files for predictive simulations from calendar year 1940 to 11940 for each tank farm, source release type, and contaminant. An input file for each tank farm provided a 3000-year historical simulation to initialize the flow field for the predictive simulations.

The same broad organization was used for TWRWP model input files, except the AX Farm retrieval leaks from the four SSTs were separated into four release simulations from the combined source release term in the TC&WM EIS, and relevant indicator contaminants wee combined into just two input files for either radionuclides or non-radiological chemicals.

Later steps were performed by directly editing copies of input files from the TC&WM EIS. The TWRWP model included a total of 24 simulations, not counting preliminary runs that tested other contaminants or parameters.

The following figures show the horizontal gridding used for each tank farm STOMP© model relative to the actual positions of the SSTs and the fence line (shown as a bold black line).

Figure 4. Plan View Map of AX Farm STOMP© Model Horizontal Gridding.

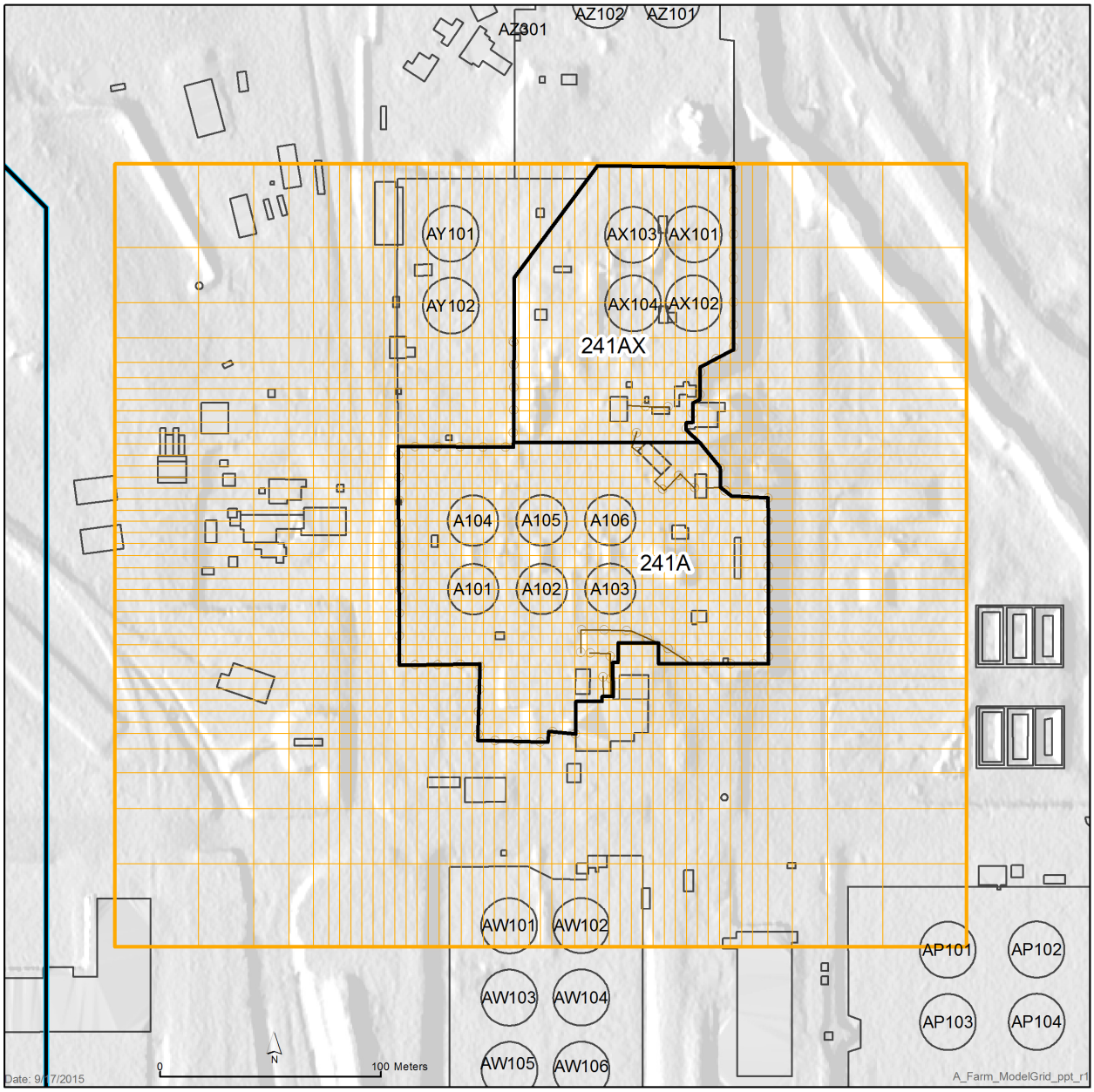


3.3 SELECT CURRENT BUILD OF STOMP© AND ADJUST INPUT FILES FOR CONSISTENCY WITH TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT

STOMP© is configuration controlled and managed under CHPRC-00176, "STOMP Software Management Plan." A verified installation of the current build was checked out as reported in Section 5. Changes implemented in builds since the TC&WM EIS were assessed to determine if any such changes required adjustments of input to yield results consistent with the model

execution at the time of the TC&WM EIS, provided such changes were not fundamental improvements over past builds.

Figure 5. Plan View Map of A Farm STOMP© Model Horizontal Gridding.



3.4 LOCATE VERTICAL REFERENCE POINTS FOR STOMP© MODEL GRIDS

To adapt the TC&WM EIS STOMP©-based models of the vadose zone to include the saturated zone, it is first necessary to establish the location of the selected water table elevation relative to contaminant sources in each model and to understand the alignment of the A Farm and AX Farm models to each other.

The TC&WM EIS model grid for AX Farm represents 82 m of the vertical thickness of the vadose zone with 41 nodes at 2-m spacing. The TC&WM EIS model grid for A Farm represents 90 m of the vertical thickness of the vadose zone with 45 nodes at 2-m spacing. The base of the TC&WM EIS model for AX Farm is a horizontal plane specified to correspond to the water table at the center of the group of AX-100-series tanks. The steady-state water table elevation predicted by the CPGWM calibration version 3.3 is approximately 119.5 m on the North American Vertical Datum of 1988 (NAVD 88) (CP-47631), with the variation across the area of the A Farm and AX Farm STOMP© model domains on the order of millimeters to centimeters.

Because the water table has risen and then fallen since Hanford operations began (see, e.g., Figure 5-7 in RPP-ENV-58578), and because the steady-state elevation may not match exactly between different models, other verifiable vertical reference points were calculated for the STOMP© models. Since the SSTs will be grouted in place under Alternative 2B, the base of the SSTs is an unchanging elevation over the period of analysis which can be used as a reference to locate vertical zones of soil properties of interest or to locate features such as the water table that have experienced elevation changes over the period of record. Multiple points from available engineering drawings were referenced to estimate and check the reliability of the tank base elevations, including the use of consistent units and vertical datums.

After determining reference elevations for each tank farm model, the transport distances between release locations and the steady-state water table were verified, and the model domains were visualized in TecPlot®† and examined to understand the positions of the releases and the water table relative to the hydrogeologic features in the vadose zone.

3.5 EXTEND STOMP© MODEL GRIDS FOR EACH TANK FARM DOWNWARD INTO SATURATED ZONE

Groundwater concentrations will be calculated in the 5-m vertical interval below the water table at the downgradient fence line. Layers can be added at the base of the model as needed. Decisions about gridding details depend on the vertical alignment of the models determined in Step 4 (see Section 6.4) and the available data to support determination of parameters in Step 6.

3.6 ASSIGN AQUIFER PARAMETERS

The saturated zone implementation has fundamental importance in controlling the amount of dilution of contaminants in water infiltrating the vadose zone as the water recharges the aquifer. The proportion of groundwater flux to the rate of recharge will determine dilution and control groundwater concentrations. Groundwater flux is determined by the hydraulic gradient and the effective hydraulic conductivity of the saturated zone across the model domain.

An assumption of steady-state groundwater flow conditions is applied in the design of various aspects of the saturated zone. Steady-state groundwater flow conditions include return of the water table to approximately its pre-Hanford elevation and a constant groundwater flux. The

† TecPlot® is a registered trademark of Tecplot, Inc. in the United States and other countries.

steady-state water table elevation provides one boundary for the region for which an effective hydraulic conductivity is calculated. The use of steady-state groundwater flow conditions even for past calendar years has little impact on groundwater concentrations, because the time lag for transport of past leaks or retrieval leaks through the vadose zone delays arrival at the water table until it has essentially stabilized. For example, Table N-52 in DOE/EIS-0391 indicates transport through the vadose zone in the 200 East area on average takes about 63 years at a recharge rate of 100 mm/yr.

The steady-state water table elevation is determined from the CPGWM calibration Version 3.3. An effective hydraulic conductivity for the extent of the saturated zone in the TWRWP model domains is determined using the CPGWM steady-state predictions for the local flux and hydraulic gradient. An effective hydraulic conductivity for the entire extent of each TWRWP model saturated zone is used in lieu of mapping discrete hydraulic conductivities for 5 layers of 25 cells each from the CPGWM to two different, highly-discretized TWRWP model grids, because it offers a straightforward and functionally equivalent approach for calculating groundwater concentrations on the small scale of transport relevant for the analysis, as well as simplifying the specification of boundary conditions. The two model grids are not aligned parallel to groundwater flow, so prescribed head boundary conditions require calculating pressures at several locations using the hydraulic gradient, which would be even more complicated if heterogeneous hydraulic conductivities were explicitly represented along the model boundaries.

In the STOMP© input files' Rock/Soil Zonation Card, a new rock/soil zone "Aquifer" is declared in order to efficiently assign properties to the upper saturated zone via multiple other cards. Parameter values are obtained from reference documents (see Section 4) or calculated on an equivalent homogeneous medium basis for the particular extent of the aquifer region included in the model.

The effective hydraulic conductivity of the region of the aquifer included in the model domains was calculated from the CPGWM calibration version 3.3 using the local values at steady state for the flux, hydraulic gradient, and saturated thickness. Model properties and steady-state results were visualized using Groundwater Vistas™‡ and ArcGIS™§. Steady-state fluxes for selected regions were extracted from the CPGWM output using ZONEBUDGET (USGS Open-File Report 90-392, "A Computer Program for Calculating Subregional Water Budgets Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model").

A square region of the CPGWM 5 cells × 5 cells (500 m × 500 m) corresponds to about the same lateral extent as the combined STOMP© model domains for A Farm and AX Farm. The square region and its CPGWM cell indices are shown in Figure 6.

The CPGWM has 7 layers (numbered top to bottom by MODFLOW convention) with variable cell heights such that cells from two successive layers may be adjacent to each other in some

‡ Groundwater Vistas™ is a trademark of Scientific Software Group, Sandy, Utah.

§ ArcGIS™ is a trademark, registered trademarks, or service marks of ESRI in the United States, the European Community, or certain other jurisdictions.

cases. In the region of Figure 6 when the CPGWM is run to steady state, Layer 1 is unsaturated, Layers 2 and 3 are partially saturated (intersect the water table), and Layers 4 through 7 are saturated. Layers 2 through 5 have similar cell heights typically around 4 m in the region of Figure 6, whereas Layers 6 and 7 each vary in cell height from about 1 m to 11 m as the TOB (top of basalt bedrock) dips generally toward the southeast (Attachment 1).

Three hydrostratigraphic unit (HSU) material types (each associated with gravel stratigraphic units recognized at the Hanford Site) with calibrated hydraulic conductivities (K) are assigned to cells in Layers 2 through 7 in the region of Figure 6: Coarse Grained Hanford (K = 17,000 m/d), Cold Creek (K = 400 m/d), and Ringold A (K = 4.8 m/d). The distribution of HSU materials is shown in the following figures:

Model layers 6 and 7 at the base of the aquifer contain only the Ringold A HSU material which has the lowest hydraulic conductivity by two orders of magnitude. These layers would be expected to carry relatively insignificant flow, are located greater than 5 m below the water table, and would be relatively challenging to implement given the dipping bedrock. Layers 2 through 5 contain mostly the Cold Creek HSU material below the water table, but the exceptionally high hydraulic conductivity of the Coarse Grained Hanford HSU cells has a strong influence on the effective hydraulic conductivity for these layers.

The steady-state water table elevation from the CPGWM is roughly 119.5 m NAVD 88. A Microsoft Excel®** spreadsheet (Attachment 1) tabulates high-precision hydraulic heads for each cell location for calendar year 2100 which is predicted to be close to steady state, and the heads are used in Attachment 1 to calculate saturated thicknesses and the hydraulic gradient. The average saturated thickness of the 25 cells (from the water table to the bottom of Layer 7) is about 23 m. The average saturated thickness above the bottom of Layer 5 is about 11 m.

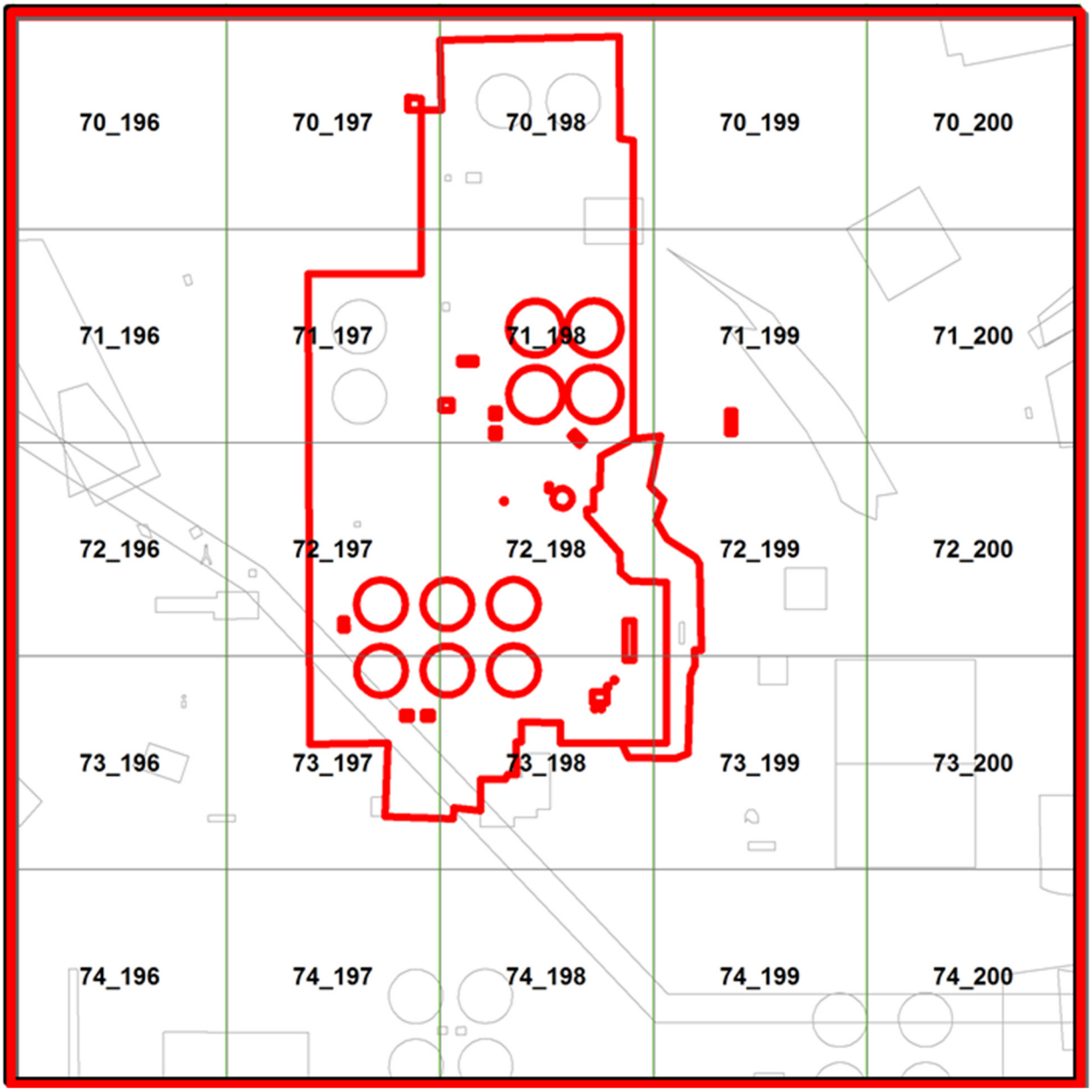
The x- and y-components of the hydraulic gradient are calculated in Attachment 1 by dividing the differences in hydraulic head between the nodes in the centers of the cells at the corners of Figure 6 by the 400-m distance between any pair of corner nodes in the x- or y-directions. The hydraulic gradient is the resultant vector from these components. Two alternate combinations of corners for component vectors result in a hydraulic gradient magnitude over the domain of about 3.0×10^{-5}. The direction of flow determined from the x- and y-components gives an angle of about 16 degrees measured south of east. This hydraulic gradient is used to calculate the effective hydraulic conductivity from which it results in the CPGWM, whereas a slightly different estimate is applied in the TWRWP model boundary conditions in Step 7 based on additional sources of data.

Flux through model Layers 2 through 5 in the square region in Figure 4 was estimated to be on the order of 300 m^3/day (Figure 8) using ZONEBUDGET (USGS Open-File Report 90-392). Zones were also specified in Layers 2 through 5 on the sides of this region and in Layers 6 and 7 underneath to obtain fluxes in adjacent regions which are sources and sinks to the region of interest. The results indicate there is indeed relatively little predicted downward flow into Layer 6 (net downward flow is approximately 1 m^3/day) or laterally through Layers 6 and 7 (net

** Microsoft Excel is a registered product of the Microsoft Corporation.

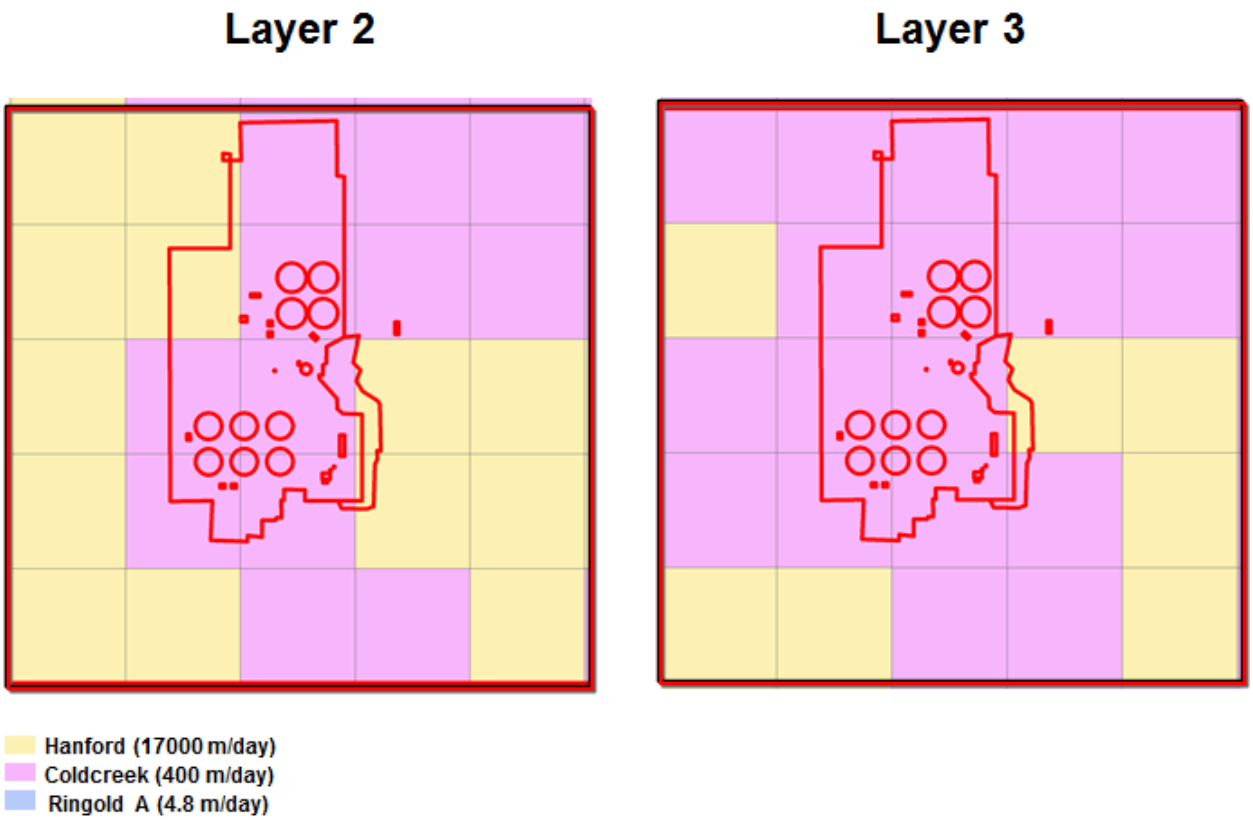
flow is approximately 3 m^3/day), such that the bottom portion of the aquifer is not expected to have much effect on transport near the water table.

Figure 6. Area of Central Plateau Groundwater Model Corresponding to Tank Waste Retrieval Work Plan Model Domains.



The flux used to calculate the effective hydraulic gradient is through a vertical cross-section orthogonal to the direction of flow. The length of the cross-section is determined by dividing the 500-m length of the side of the region by the cosine of 16 degrees, yielding 520 m.

Figure 7a. Hydraulic Conductivities of Central Plateau Groundwater Model Layers 2 and 3 Cells in Waste Management Area A/AX Region.



From Darcy's law, the horizontal effective hydraulic conductivity (K) of Layers 2 through 5 in the region of Figure 6 is calculated from the steady-state flux (Q), hydraulic gradient (i), average saturated thickness (b), and cross-sectional length (l):

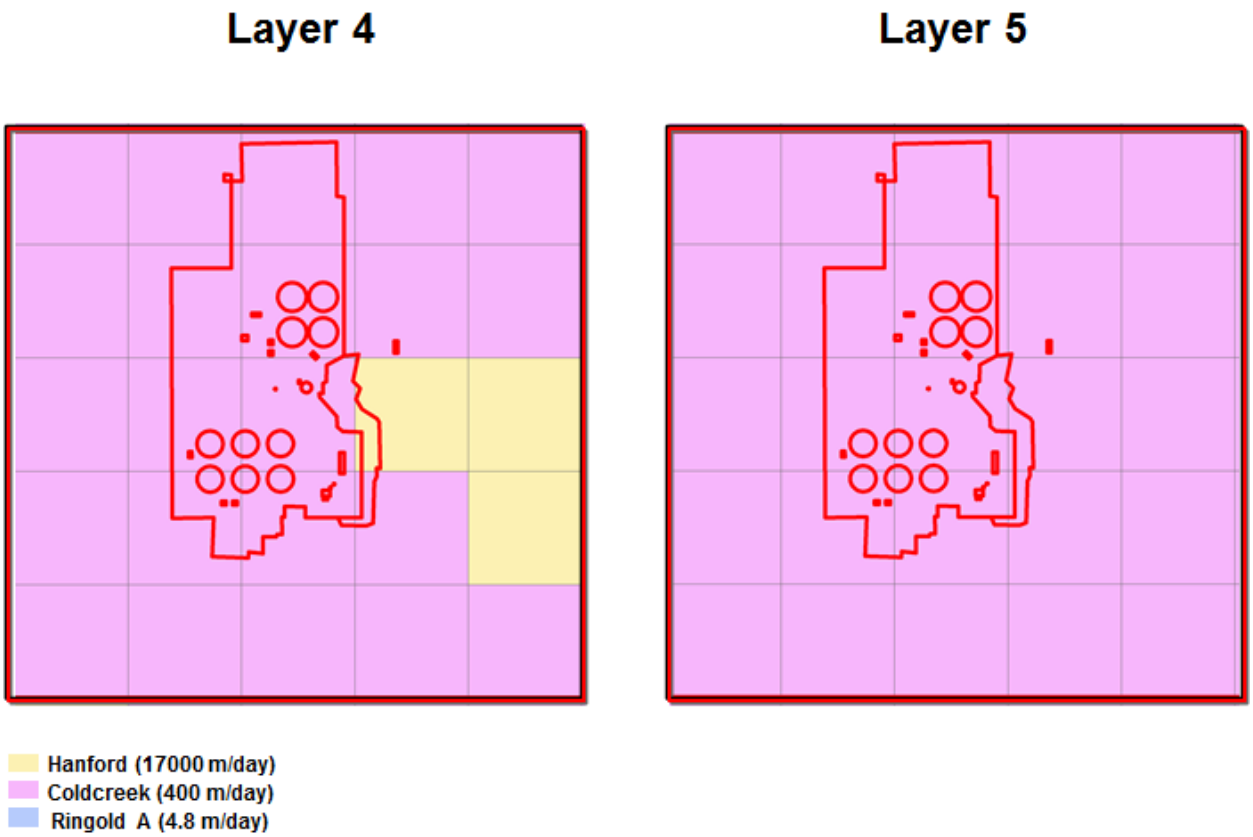
$$K = \frac{Q}{i \times b \times l}$$

$$K = \frac{300\ \frac{m^3}{d}}{(3.0 \times 10^{-5}) \times (11.0\ m) \times (520\ m)}$$

$$K \approx 1{,}750\ m/d$$

The vertical effective hydraulic conductivity of the region is assumed to be one tenth the horizontal hydraulic conductivity, or 175 m/d.

Figure 7b. Hydraulic Conductivities of Central Plateau Groundwater Model Layers 4 and 5 Cells in Waste Management Area A/AX Region.



3.7 ASSIGN BOUNDARY CONDITIONS AND INITIAL CONDITIONS

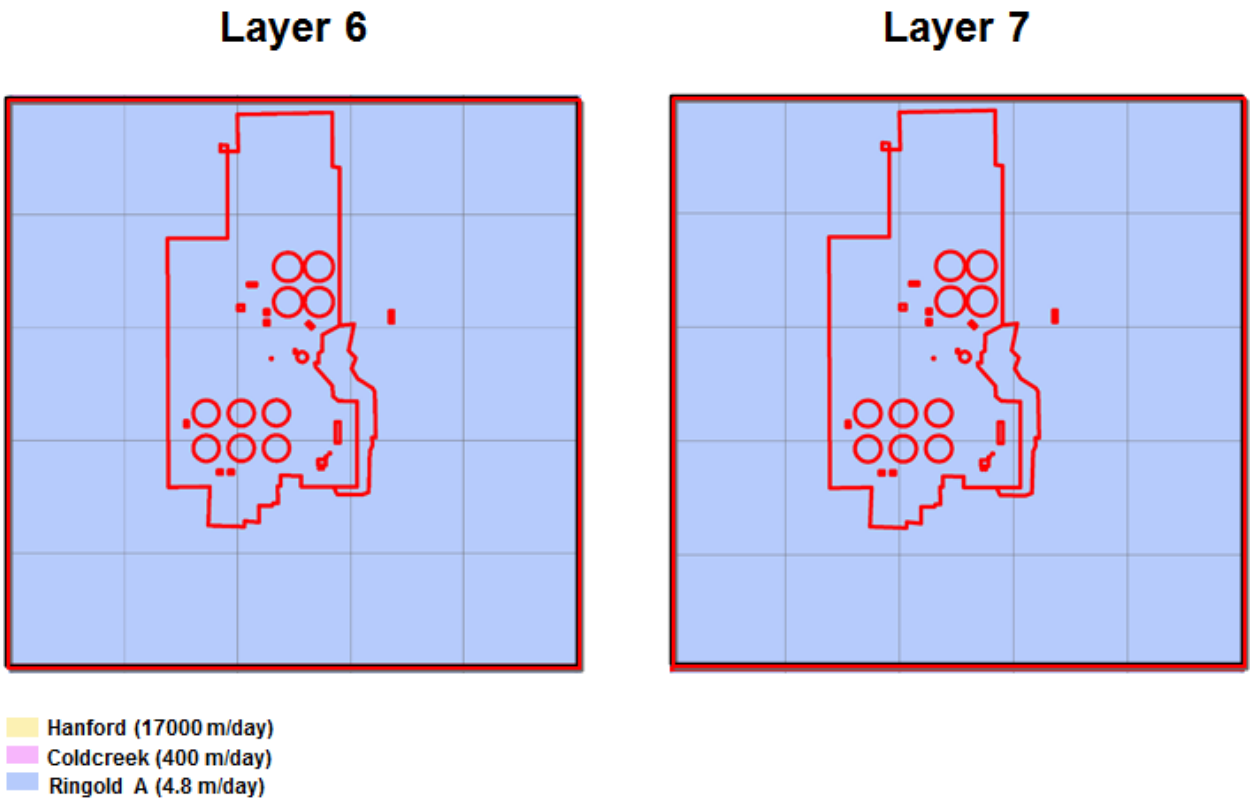
Saturated zone boundary conditions are calculated using the effective hydraulic conductivity value and a generalized estimate of the hydraulic gradient that captures the order of magnitude and direction (with flow approximately 45 degrees south of east) typical of both recent conditions applicable to the approaching time of arrival of past leaks at the water table and to the CPGWM predicted steady-state conditions applicable to arrival of other source terms. Saturated zone flow is specified using Neumann boundary conditions on the west and north to prescribe i and j components of flux and "Hydraulic Gradient" boundary conditions on the east and south which are used as prescribed head boundary conditions.

The top boundary conditions for infiltration are unchanged from the TC&WM EIS (aside from re-indexing). The Dirichlet condition on former bottom boundary is deleted and no new bottom boundary conditions for the models are specified, so a no-flow condition is imposed by default.

Using the "Hydraulic Gradient" boundary condition option, the pressure is specified at the east or south cell face of the lowest cell in a vertical range from the model base to the water table, and STOMP© calculates the pressures at the same-side cell face for cells in the rest of the vertical range as part of the boundary condition specification (PNNL-15782). The corners of the A Farm

model and AX Farm model domains are close together and the lateral component of the hydraulic gradient is extremely flat, so the difference caused by using the same pressure for slightly different locations in different simulations is negligible.

Figure 7c. Hydraulic Conductivities of Central Plateau Groundwater Model Layers 6 and 7 Cells in Waste Management Area A/AX Region.

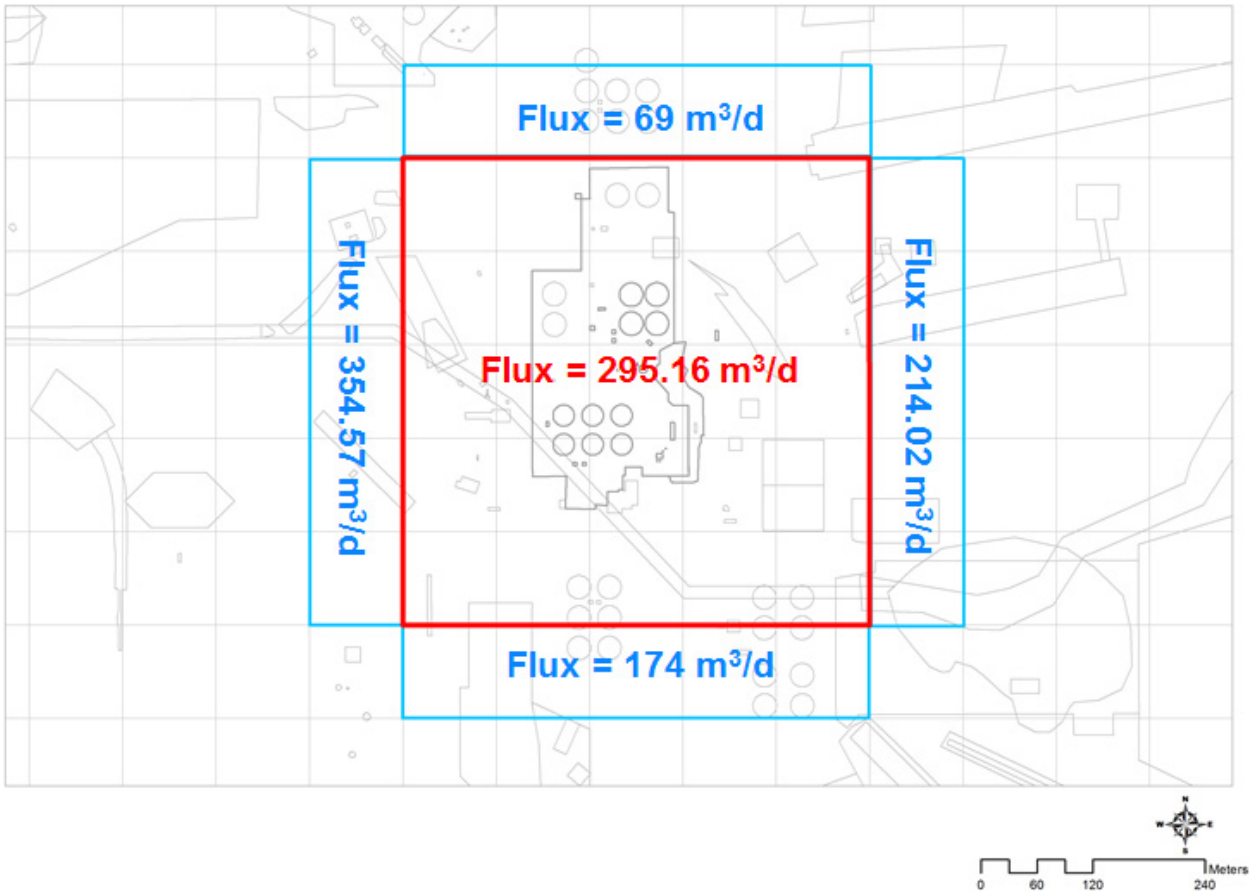


To calculate the prescribed heads for the remaining cells on the east and south boundaries and the prescribed fluxes on the west and north boundaries, estimates of the hydraulic gradient from current measurements, past analyses, and modeled steady-state conditions were considered. Section 3.6 detailed the CPGWM prediction of the steady-state hydraulic gradient at 3.0×10^{-5} to the east southeast. The best available water table maps of current conditions and documents summarizing past analyses provide estimates for comparison.

A map of the water table on pp.13 of CHPRC-02485-VA shows a pair of hydraulic heads (h) from calendar year 2013 average measurements (with corrections as described in Section 2.2) from wells approximately aligned with the regional southeastward flow and located on either side of WMA A/AX (with values consistent with nearby data) provides a simple method to estimate the hydraulic gradient (i) over a distance (l) on the local scale of WMA A/AX as follows:

$$i = \frac{dh}{dl} \approx \frac{121.787\ m - 121.784\ m}{0.32\ in.\,printed\ length \times \dfrac{500\ m\ scalebar}{0.59\ in.\,printed\ scalebar}} = 1.1 \times 10^{-5}$$

Figure 8. Central Plateau Groundwater Model Steady-State Flux in Layers 2 through 5 in Waste Management Area A/AX Region.



The calendar year 2013 average heads provide relatively good indication of the flow direction in the absence of artificial discharges since relatively small discharges occurred from 2011 through 2013 at the TEDF facility (typically one of the stronger influences) east of the map area. The indicated flow direction is to the southeast, consistent with historical estimates (RPP-ENV-58578). The above approach is acknowledged to have limitations in accuracy in spite of efforts to reduce uncertainty in the measurements underlying the water table map.

The conclusion from the preceding analysis is that a local hydraulic gradient of 1×10^{-5} toward the SE for the model domains, as estimated in RPP-ENV-58578 (pp. 5-8), is reasonable to represent the order of magnitude of both current measurements and steady-state CPGWM predictions. Relative to the slightly higher CPGWM prediction, use of the 1×10^{-5} magnitude in specifying boundary conditions yields lower groundwater flux and thus lower contaminant dilution. It is possible a more precise hydraulic gradient may be selected in a performance assessment based on a more extensive analysis considering additional information.

The x-component of the hydraulic gradient (i_x) and the y-component of the hydraulic gradient (i_y) are calculated for the southeastward flow direction consistent with historical observations (RPP-

ENV-58578 Rev.0) and recent conditions indicated by the 2013 map in CHPRC-02485-VA as follows:

$$i_x = 1 \times 10^{-5}[-\cos(45\ degrees)]$$

$$i_y = 1 \times 10^{-5}[\sin(45\ degrees)]$$

The prescribed flux (q_x) into the saturated zone along the entire length of each tank farm model's western domain boundary is calculated as follows:

$$q_x = -K \times i_x$$

The prescribed flux (q_y) into the saturated zone along the entire length of each tank farm model's northern domain boundary is calculated as follows:

$$q_y = -K \times i_y$$

As shown in the following equations, prescribed heads on the eastern and southern boundaries are calculated using the x- and y-components of the hydraulic gradient to adjust the hydraulic head for the bottommost node (*k* index 1) at the *n*th index in *i* or *j* along the given boundary from the 119.5-m value at the node in the bottom SE corner of each model grid (at y_{SE} or *j* index 1 and x_{SE} or the maximum *i* index, i_{max}) and converting to pressure (pressures for nodes up to the water table are calculated by STOMP© using the "Hydraulic Gradient" option):

$$h_{i=n,j=1,k=1} = (119.5\ m) + i_x(x_{i=n} - x_{SE})$$

$$h_{i=i_{max},j=n,k=1} = (119.5\ m) + i_y(y_{j=n} - y_{SE})$$

$$P_{i=n,j=1,k=1} = P_{atm} + \frac{dP}{dz} \times \left(z_0 + \frac{\Delta z_1}{2} - h_{i=n,j=1,k=1}\right)$$

$$P_{i=i_{max},j=n,k=1} = P_{atm} + \frac{dP}{dz} \times \left(z_0 + \frac{\Delta z_1}{2} - h_{i=i_{max},j=n,k=1}\right)$$

All saturated zone boundary conditions are calculated in Attachment 1, including formatting for STOMP© input instructions which were subsequently edited to include appropriate line breaks and numbers of commas for delimiting solute boundary conditions as applicable.

All contaminant source release terms are located in the interior of the domain, so the only required boundary conditions for solute fluxes are indicated by using the "Outflow" option for the saturated zone nodes on the west, north, east, and south sides of the model domains. The base of the model defaults to a zero flux condition which is expected to have little effect on model results if the base elevation is more than 5 m below the water table, which is the case when the 11-m average saturated thickness of relatively conductive gravels in the CPGWM is used to locate the base of the model.

For each tank farm model, a historical 3,000-year period of flow is simulated to initialize conditions in the vadose zone. Moisture content and fluxes at the end of the 3,000-year period are checked to verify steady-state conditions, and those conditions are applied as initial conditions (via a restart file that is output from the historical simulation) to predictive transport simulations carried out for a 10,000-year assessment period over the calendar years 1940 to 11940.

Initial conditions for the historical flow simulations are more or less arbitrary. The water table is initially prescribed several meters higher than the steady-state value, and over the historical simulation period of 3,000 years the water table lowers and the model reaches equilibrium reflecting the specified recharge and other boundary conditions. See Section 4 for details.

3.8 MODIFY TIME-STEPPING TO ACCOMMODATE SATURATED ZONE ADVECTION

Given that the models now contain a saturated zone with rapid advection of solutes, it is necessary to re-evaluate the constraints on time steps for solution of the flow and transport equations.

The Solution Control Card input for STOMP© (PNNL-15782) for the historical flow simulations was essentially unchanged from the TC&WM EIS input, except more maximum iterations were allowed in case the addition of the saturated zone and perturbing of initial conditions caused them to be necessary.

For predictive transport simulations, the maximum time step was reduced to 1 year. The "Courant" option is specified for transport simulations as in the TC&WM EIS files, so STOMP© automatically reduces the time step as necessary to satisfy the Courant-Friedrichs-Lewy (CFL) condition (PNNL-15782). However, an upper limit on the time step set reasonably close to the CFL limit requires fewer iterations of time step reductions for each solute and thus potentially reduces the total time for simulations to complete.

The maximum time step for transport simulations is set to 1 year primarily for efficient numerical convergence purposes, but this also causes results to be output with enough frequency to allow the predicted time of peak groundwater concentration to be reported with precision (but not accuracy) to the nearest year, as such results have been reported in past TWRWP analyses (RPP-22393).

3.9 ASSIGN ANY TRANSPORT PARAMETERS FOR INDICATOR CONTAMINANTS NOT SPECIFIED IN THE TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT

Indicator contaminants identified in Step 1 may include some of the same contaminants simulated in the TC&WM EIS models, other contaminants with properties provided in the TC&WM EIS analysis, or contaminants for which parameter estimates must be obtained from

other sources. This section explains the other sources considered in order to estimate distribution coefficients, effective diffusion parameters, and decay half-lives.

Distribution coefficients (K_d values) for adsorption of contaminants to media in the vadose zone and saturated zone are specified in the Solute/Porous Media Interaction Card. In the TC&WM EIS input files the same K_d values for each contaminant are applied to all geologic media, and the same is done in the TWRWP model input. For any additional contaminants selected as indicators, K_d values can be obtained from published data for similar sediments or estimated from values for similar contaminants. K_d values tend to be site-specific, so the latter approach is preferred given the available database of K_d values at the Hanford Site for many contaminants. A default K_d of zero is biased toward more rapid transport. However, since indicator contaminants tend to be selected in part on the basis of high mobility, any underestimation of their K_d values from using the default value is relatively small, and the default value simply implies additional indicator contaminants have low adsorption similar to contaminants already included from the TC&WM EIS input. K_d values are also available from analyses with the DMT in DOE/ORP-2005-01 (see Tables 3-7 and 3-8).

Effective diffusion parameters in TC&WM EIS input files were specified in the Solute/Fluid Interaction Card with the "Conventional" option and a value for the aqueous-phase molecular diffusion coefficient at 20°C. For any additional contaminants selected as indicators in the TWRWP model, the same can be done using a value of the aqueous-phase molecular diffusion coefficient either published for that contaminant, assumed by directly using a published value for a similar contaminant, or estimated by adjusting a published value for a similar contaminant. In the last case, a simple estimation method depending on only the molar masses (m) of two structurally similar contaminants with the known and unknown diffusivities (D) is stated by Equation 9-30 in Environmental Organic Chemistry (Schwarzenbach et al. 1993):

$$\frac{D_{w,unkown}}{D_{w,known}} \cong \sqrt{\frac{m_{known}}{m_{unknown}}}$$

Although Schwarzenbach et al. (1993) discuss the development of their Equation 9-30 in the context of organic molecules, there is no assumption in its derivation precluding its use for inorganic chemicals as well, and the EMCF authors are aware of its broader use in actual practice in other analysis contexts.

Following the method in TC&WM EIS input files, non-radiological chemicals are specified as effectively non-decaying by assigning an arbitrarily large half-life of 1×10^{38} years in the Solute/Fluid Interaction Card (PNNL-15782). No reactions other than radioactive decay or surface adsorption were directly simulated in the TC&WM EIS models, and no indicator contaminants were identified that had substantially different chemical properties than the contaminants already considered, so no further assumptions of reactions were made.

3.10 POPULATE SOURCE RELEASE TERMS OF INDICATOR CONTAMINANT INVENTORIES AND VOLUMES

Contaminant source release terms involve specifying contaminant inventories, their location, and the timing and nature of their release.

Retrieval leaks from the AX-100-series tanks were simulated as unit inventory releases (1 Ci or 1 kg) of each contaminant, and after completion of the simulations, results were scaled by inventories based on analysis using the OLI Stream Analyzer (RPP-RPT-58867). All other source term releases involved direct simulation of specific inventories based on the TC&WM EIS input files. Nitrite and nitrate source terms were recalculated from the TC&WM EIS nitrate source terms for all affected sources by using the raw inventory data in the TC&WM EIS references (Table D.1 of Appendix D in DOE/ORP-2003-02, Inventory and Source Term Data Package except as noted) to determine the fraction of each species as nitrate and then converting the mass of nitrite by stoichiometry (Attachment 2). Fractions as nitrate were estimated for the A Farm and for the AX Farm using the sums of inventories for the SSTs in each tank farm. Fractions were multiplied by the source term release rates for each corresponding period of time in the TC&WM EIS input files, and then the nitrite release rates were converted from a nitrate basis to a nitrite basis by stoichiometry. Details for specific source terms are discussed in the following sections.

3.10.1 Past Releases

The TC&WM EIS past leaks source terms included large waste losses associated with Tanks A-104 and A-105, and much smaller losses associated with Tanks A-103, AX-102, and AX-104.

Past releases are implemented in the TC&WM EIS as liquid releases at the nodes located at the bases of the associated tanks. The footprint of a given tank is a square comprised of 4 nodes on each side at 5-m spacing, i.e., a 400 m^2 area approximating the roughly 410 m^2 area of a 75-ft diameter circular tank. For each tank, the estimated total release volume and inventory are distributed uniformly over the tank footprint and released at a uniform rate for a period of one year during the earliest calendar year of any known or suspected releases.

For example, tank A-105 had a known, large release of tank waste in 1965, possibly a smaller release in 1963, and possible loss of much greater volumes of initially clean water added to the tank from 1970 to 1978 for the purpose of evaporative cooling (RPP-ENV-37956, Appendix B, pp. B-52 to B-55). The releases are simulated as a single release of the total inventory and total volume of waste and water in the calendar year 1963 (unchanged from the TC&WM EIS).

A release was simulated for tank A-104 in the calendar year 1975. The inventory was of a similar magnitude to that of A-105, but the volume was much smaller, so the source release term causes contaminants from A-104 to enter the vadose zone at higher concentrations in less volume at a later date relative to A-105.

Tanks A-103, AX-102, and AX-104 have historically been classified as "assumed leakers" and that designation had not been formally changed at the time the TC&WM EIS was prepared. The TC&WM EIS modelers used estimates of possible leak inventories and volumes for these tanks from multiple sources and simulated releases occurring in the calendar years that the tank farms began operating (1956 for A-103 and 1965 for AX-102 and AX-104). Since then, formal re-assessments of these three tanks in accordance with Engineering Procedure TFC-ENG-CHEM-D-42, "Tank Leak Assessment Process" determined they did not leak and should be reclassified as sound (RPP-ASMT-42278, "Tank 241-A-103 Leak Assessment Report"; RPP-ASMT-42628, "Tank 241-AX-102 Integrity Assessment Report"; RPP-ASMT-57574, "Tank 241-AX-104 Integrity Assessment Report"). Conversely, ongoing updates to the Soil Inventory Model Rev. 1 (RPP-26744, "Hanford Soil Inventory Model, Rev. 1") based on the recent tank farm leak assessment (RPP-ENV-37956) may include some small unplanned releases in WMA A/AX that were not modeled in the TC&WM EIS or that were approximated as part of the tank past leaks terms. Because the TC&WM EIS past leaks source release terms are currently the most sophisticated complete analysis of past releases in WMA A/AX, they are retained with the existing basis.

Whereas fractions of nitrite and nitrate based on tank inventories in Table D.1 of Appendix D in DOE/ORP-2003-02 Rev. 0 are directly applicable to retrieval leaks, tank residuals, and ancillary equipment residuals source terms that were used in the TC&WM EIS input files, the past leaks inventory estimates in the TC&WM EIS differed from DOE/ORP-2003-02 Rev. 0 as noted. After verifying based on multiple contaminants that input file inventories used in the TC&WM EIS corresponded to those Table 4-1 in RPP-14430 for A-104 and to results from RPP-26744 for A-105, the nitrite and nitrate inventories in those documents were divided by the number of nodes in a tank footprint (16) and the number of seconds in the one-year period assumed for release to obtain the release rates per node for the TWRWP input. For the small tank A-103 footprint past release, the fractions used for other source release terms for the A Tank Farm as a whole were applied to the TC&WM EIS nitrate input file release rate. The sum of the released inventories on a nitrate basis was confirmed to match the total A Farm past releases inventory for nitrate in Table D-27 of DOE/EIS-0391 Appendix D (see Attachment 2).

3.10.2 Retrieval Leaks

Retrieval leaks at AX Farm are implemented as liquid releases at the nodes located at the bases of the associated tanks. As for past leaks, the footprint of a given tank is a square comprised of 4 nodes on each side at 5-m spacing. For each tank, a hypothetical release volume of 4,000 gallons and a unit inventory (1 Ci or 1 kg) are distributed uniformly over the tank footprint (16 nodes) and released at a uniform rate for a period of one year during the calendar year 2018. These are the same assumptions used in the TC&WM EIS except for the release area. Attachment 2 shows the resulting release rates for solutes and fluxes.

Note this EMCF reports peak groundwater concentrations per unit inventory from AX Farm retrieval leaks, and as a point of reference, the groundwater concentrations from scaling the results by tank-specific potential leak concentrations of indicator contaminants based on analysis using the OLI Stream Analyzer (RPP-RPT-58867) multiplied by hypothetical 4,000-gallon retrieval leak volumes.

Retrieval leaks at A Farm follow the TC&WM EIS implementation in which leaks from all 6 SSTs of 4,000 gallons per tank occur simultaneously. The TC&WM EIS assumption for inventory involved simple dilution of a composite waste composition reflecting the whole tank farm inventory, and the retrieval leak inventory was distributed uniformly throughout the volume released. A Farm retrieval leaks are distributed uniformly over the tank farm footprint of 160 nodes at 5-m to 5.5-m spacing at the base of the tanks and released at a uniform rate for a period of one year during the calendar year 2018.

3.10.3 Tank Residuals

Releases of indicator contaminants from tank residuals in both A Farm and AX Farm follow the TC&WM EIS implementation using source release terms from STOMP© input that were created from a partitioning-limited, convective-flow release model. In the STOMP© input, contaminants are released into the flow field resulting from the prescribed infiltration rates, and there is no additional release of water. Releases at the bases of the tanks are evenly distributed across the total footprint of the SSTs (and the spaces in between) at each tank farm for a series of step changes in the rate of release for a long period of time following closure. The AX Farm combined tanks footprint is a rectangle containing 100 nodes at 4-m to 5.5-m spacing. The A Farm combined tanks footprint is a rectangle containing 160 nodes at 5-m to 5.5-m spacing. The TC&WM EIS applied assumptions consistent with Alternative 2B to the inventories in Table D.1 of Appendix D in DOE/ORP-2003-02. The only adjustment in the TWRWP model analysis is the re-calculation of nitrite and nitrate inventories previously described.

3.10.4 Ancillary Equipment Residuals

The discussion of tank residuals in Section 3.10.3 applies to releases of ancillary equipment residuals as well. The TC&WM EIS assumptions regarding residuals in ancillary equipment lead to inventories proportional to those of tank residuals, on the same order of magnitude but somewhat lower.

3.11 SPECIFY OUTPUT OF FENCE LINE WATER AND SOLUTE FLUXES ACROSS SURFACES FOR REPORTING IN THE SURFACE FLUX CARD

Volumetric fluxes of water and mass fluxes of indicator contaminants (solutes) at the fence line are output for use in calculating groundwater concentrations.

The tanks in each tank farm are located in the center of the respective model grids where the grid spacing provides the highest resolution (see Figures 4 and 5). The grid resolution is relaxed toward the edges of the domain. As a result, the WMA fence line overlies nodes of differing dimensions depending on which tank farm model grid is used, and the southernmost portion of the fence line lies outside the Tank Farm AX model grid. Releases from sources in each tank farm are simulated on the appropriate tank farm model grid such that resolution is maximized at the release source and the nearest downgradient portion of the fence line where the maximum impact is expected to occur.

Surface files are used to output solute fluxes and water fluxes for the appropriate fence line nodes at each time step. Fluxes for groups of nodes in discrete sections of the fence line are output to different surface files which are named to reflect the side of the WMA where the section of the fence line is located (N, E, S, or W). Surface files in historical flow simulations are also specified to report water fluxes into and out of the vadose zone over the full horizontal extent of each model domain and water fluxes into and out of the saturated zone over the length of each side of each model domain. Some additional surface files were output for internal checking purposes or unused alternative calculations and are not referenced further in this EMCF.

The 5-m interval below the water table is the interval used for comparison with groundwater protection standards. Fluxes across multiple nodes covering the 5-m vertical interval are integrated by STOMP© by specifying a range of *k* indices in the input instructions for the Surface Flux Card.

3.12 RUN HISTORICAL SIMULATIONS IN STOMP© MODELS TO OBTAIN INITIAL CONDITIONS FOR CALENDAR YEAR 1940 AND CONFIRM STEADY STATE MOISTURE CONDITIONS

The historical flow simulations described in previous steps are run with the executable selected in Step 3. Moisture content is output at every time step for selected nodes representing a range of rock/soil zones in the vadose zone and aquifer. These were examined to confirm stable values are attained within the simulated period of time, and that the values are reasonable with respect to the nodes' porosities and stratigraphic positions. Water fluxes from surface files were similarly examined to verify stabilization of reasonable values given the boundary conditions. At steady state the model should have no net change in storage, so the water fluxes from the surface files were checked to verify that the fluxes into each model domain from the top, west, and north boundaries balanced the fluxes out of the east and south boundaries to a high level of precision.

3.13 RUN PREDICTIVE SIMULATIONS IN STOMP© MODELS TO OBTAIN FENCE LINE WATER AND SOLUTE FLUXES

The predictive flow and transport simulations described in previous steps are run with the executable selected in Step 3 and the restart files generated at the end of the historical flow simulations.

3.14 CONVERT FENCE LINE WATER AND SOLUTE FLUXES TO FENCE LINE GROUNDWATER CONCENTRATIONS AND DETERMINE THE TIME AND LOCATION OF PEAK IMPACT OF EACH INDICATOR CONTAMINANT FOR EACH SIMULATION

Solute fluxes and water fluxes into a 5-m interval below the water table were both output at every time step for each specified node along the fence line (or group of nodes where solute flux is expected to be zero as in upgradient locations). Within the resolution of each STOMP© model grid, groundwater concentrations of each indicator contaminant were calculated at every point along the downgradient fence line at every time step. Dividing the solute flux by the water flux across the same surface yields the groundwater concentration.

The maximum concentration of each contaminant and the time at which it occurs are reported for each source. Predictive simulation times in units of years are output by STOMP© using the average length of a year on the Julian calendar and are reported as approximate Gregorian calendar years by adding 1,940 (i.e., leap years are not tracked precisely).

Post-processing of STOMP© output was performed with the surfaceTo.pl Perl script provided by the STOMP© authors and with FORTRAN codes that were verified during the technical review of this report with independent Microsoft Excel® post-processing, as noted in Section 5.2.1.1.

4.0 ASSUMPTIONS AND INPUTS

This section lists assumptions and inputs necessary to perform the calculations in the EMCF and to understand the context of the reported results. Copies of original materials supporting the assumptions and inputs are included in Attachment 3.

- Retrieval leaks at the center of this analysis are hypothetical events for which various assumptions are required which should not be construed as anticipated features, since it is not anticipated the leaks themselves would occur or be allowed to occur. For example, the SSTs in WMA C were retrieved with no leaks.

- It should be emphasized that model predictions into future centuries and millennia have uncertainties in timing of peak groundwater concentrations larger than a few years.

- Indicator contaminants accounting for 95% of risk metrics were determined from Tables Q-69, Q-92, Q-100, and Q-108 in Appendix Q of the TC&WM EIS (DOE/EIS-0391).

- Retrieval leak inventories are determined using leak concentrations from the OLI Systems Inc. Stream Analyzer reported in RPP-RPT-58867. Assumptions in the source calculations are carried forward.

- Retrieval leaks in the AX Farm are assumed to be distributed over the footprints of the respective tanks. The TC&WM EIS simulated leaks from all 4 AX Farm SSTs simultaneously using a single source release term with a rectangular footprint of 100nodes of variable spacing, including the SSTs and the nodes in between. The individual tank footprints without the nodes between the tanks distribute the equivalent portion of the water release over a smaller area, resulting in a somewhat higher release rate than assumed in the TC&WM EIS. An assumed 4,000-gallon retrieval leak volume is arbitrary with respect to the TWRWP analysis, but using larger volumes with unit inventory releases would cause more dilute initial release concentrations, so as a transport modeling input the TC&WM EIS value of 4,000 gallons per leak is a conservative assumption. With respect to the effect on inventory assumptions, arbitrarily large volumes may be assumed and applied to scale the groundwater concentrations simulated for unit inventories.

- Following the TC&WM EIS assumption of the calendar year 2018 for all 4 retrieval leaks in AX Farm is arbitrary, since all the retrieval leaks are hypothetical. The modelers do not have firsthand knowledge of the schedule of retrieval operations; rather, the assumption is considered adequate because the models release the retrieval leaks together in time (close would be adequate) with reasonable lags between past leaks, retrieval leaks, and changes in infiltration conditions in 2050 at the assumed date of closure.

- Past leaks use the same inventory and release implementation as the TC&WM EIS, which includes releases from not only tanks A-104 and A-105, but also tanks A-103,

AX-102, and AX-104. The exception to use of the same inventory is the re-calculation of nitrite and nitrate source terms as described in Section 3.10.

- Release of source terms for residual waste from tanks and from ancillary equipment were each based on a partitioning-limited, convective-flow release model assumed for grout-stabilized waste (DOE/EIS-0391 Appendix M). These source terms are implemented in the STOMP©-based models as gradual releases of contaminant mass that are implicitly related to the recharge conditions. K_d values applicable to the grouted waste in the release model were 1) 0 mL/g for the nonradiological indicator contaminants, 2) 1 mL/g for ^{99}Tc, and 3) 50 mL/g for ^{129}I (DOE/EIS-0391 Tables M-7 and M-8). (These K_d values apply only to transport within the residual waste and not to the vadose zone or aquifer). Note that other recent tank farm assessments have alternatively considered diffusion-controlled and/or solubility-controlled release models for tank residuals that generally predict lower peak concentrations and later arrival times.

- In the TC&WM EIS implementation for ancillary equipment residual waste releases, the elevation of releases was several meters deeper than the typical elevation for ancillary equipment in WMA A/AX. Any underestimation of peak arrival times for this source term was assumed to be small and to not warrant a full re-evaluation of the release implementation for the TWRWP model.

- The van Genuchten-Mualem parameterization ("A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils" [van Genuchten 1980], "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media" [Mualem 1976]) of the vadose zone is unchanged from the TC&WM EIS.

- Together with previously determined long-term average infiltration rates for undisturbed and disturbed site soils/backfill, the engineered measures in the selected Alternative 2B lead to a defined series of step changes in infiltration rates that are commonly adopted as boundary conditions in Hanford Site modeling analyses (see DOE/RL-2011-50, Section 4.5 for discussion of available data leading to the recommended infiltration rates). (The TWRWP model retains the common infiltration conditions in the TC&WM EIS STOMP© models, which are consistent with other current site models per DOE/RL-2011-50, and does not attempt analysis of other conditions explored as sensitivity cases in assessments of broader scope, such as the TC&WM EIS or subsequent performance assessments). Areas with undisturbed soils with native vegetation are assigned a constant infiltration rate of 3.5 mm/year throughout the period of analysis. These conditions are also assumed to exist for a long period of historical simulation prior to Hanford Site operations that is used to establish the initial conditions for predictive simulations beginning in calendar year 1940. Disturbances related to construction and operation of tank farms (e.g., excavation, backfill, prevention of vegetation) are represented by a change in infiltration rate to 100 mm/yr from the year of initial operations at each tank farm (1956 for A Farm and 1965 for AX Farm) until assumed closure in calendar year 2050. The barrier is assumed to limit infiltration to 0.5 mm/yr from 2050 until 2550, and then barrier degradation is assumed to yield the long-term average infiltration rate of 3.5 mm/yr for the rest of the period of analysis. The

existing TC&WM EIS STOMP© models adopt the simplifying assumption that the infiltration rate step changes apply over the rectangular footprint containing all the SSTs in each tank farm (the relevant source area for contaminant releases) and the long-term average applies everywhere else.

- Boundary conditions for the saturated zone assumed steady-state flow to the southeast at a hydraulic gradient of 1×10^{-5}. Local-scale saturated zone boundary conditions and material properties were developed from an evaluation of hydraulic properties used in the Central Plateau Groundwater Model (CPGWM) Calibration Version 3.3 (CP-47631, Rev. 2, Version 6.3.3) in conjunction with up-to-date hydrogeologic observations and local groundwater elevation trends as summarized in RPP-ENV-58578, SGW-54165, and CHPRC-02485-VA.

- Initial conditions for the historical flow simulations are more or less arbitrary. The intention was to sufficiently perturb conditions away from steady-state to allow the model to establish steady-state under the prescribed boundary conditions without unnecessary bias from the modeler. The water table is initially prescribed several meters higher than the steady-state value. Reference is made to the hydrostatic vertical gradient value of -9793.5192 1/m and atmospheric pressure value of 101325 Pa to provide initially saturated conditions to an appropriate elevation, and for the initially unsaturated layers a small fraction of each of these values is applied such that the vadose zone has an arbitrary water content. Over the historical simulation period, the water table lowers and the vadose zone receives infiltration and drains to equilibrium. Broadly speaking, this is not unlike the physical system interpreted to have established moisture conditions prior to site development, in the sense that Pleistocene floods inundated the basin to elevations well above ground surface (RPP-ENV-58578), so the vadose zone would have become saturated and then had to drain during Quaternary time prior to the water table achieving its level as of 1940. The long-term average infiltration rate is based on evidence entirely from this post-flooding period of time (see DOE/RL-2011-50, Section 4.5).

- The aquifer total porosity and diffusive porosity are each assigned a value of 0.2 as recommended for the saturated gravel strata in the local vicinity (RPP-14430, Section 2.4.2.4).

- Saturated zone hydraulic conductivity values of 1750 m/d in the x- and y-directions and 175 m/d in the z-direction are based on the local-scale effective hydraulic conductivity (for the upper 11 m of the saturated zone over the combined domains of the A Farm and AX Farm models) derived from the CPGWM calibration Version 3.3 local steady-state flux and hydraulic gradient.

- A longitudinal dispersivity of 1 m and a transverse dispersivity of 0.1 m are used for the aquifer based on the minimum lateral distance between sources at SSTs and the WMA fence line of approximately 10 m (Figure 4). A ratio of longitudinal dispersivity to the simulated scale of transport of 0.1 and a ratio of transverse dispersivity to longitudinal dispersivity of 0.1 are common modeling assumptions (e.g., “Three-Dimensional Stochastic Analysis of Macrodispersion in Aquifers” [Gelhar and Axness 1983];

"Stochastic Subsurface Hydrology from Theory to Applications" [Gelhar 1986]) and are consistent with the method of estimation in the TC&WM EIS. The TC&WM EIS was concerned with much larger transport distances on the order of kilometers, so it applied a Gelhar-style scale-dependent dispersivity function (Gelhar 1986) up to a threshold distance using a longitudinal dispersivity scaling factor of 0.1 and a ratio of transverse dispersivity to longitudinal dispersivity of 0.1 (see DOE/EIS-0391 Appendix O). Over the relatively short transport distances of 10 m to 100 m in the TWRWP models, a constant value was considered adequate, and the selected value was intended to place more emphasis on the minimum distance analyzed than on longer scales with higher dispersion. Aquifer dispersivity values are coincidentally the same as for media in the vadose zone, but the vadose zone parameterization is adopted from the TC&WM EIS models in which it was developed from other considerations.

- Distribution coefficients (K_d values) for each contaminant are those used in the TC&WM EIS (DOE/EIS-0391 Appendix N Tables N-2 and N-3) and have the same values for all geologic media in the vadose zone and saturated zone. The K_d value for nitrite is zero as used with past DMT analyses (see DOE/ORP-2005-01 Tables 3-7 and 3-8).

- Peak impacts from retrieval leaks from AX Farm tanks are assumed to be additive, i.e., releases from the AX Farm tanks are close enough together in space and time that peak impacts arrive close together at the fence line in space and time. Peak impacts from A Farm and AX Farm sources are assumed not to be additive based on the flow direction to the southeast and the distance between the A Farm tanks and the AX Farm tanks.

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 EXEMPT SOFTWARE

Microsoft Excel®†† is site-licensed software used to calculate source release terms; to prepare boundary conditions; and to calculate effective hydraulic conductivities for input to modeling. The Excel® spreadsheets used for these purposes are wholly incorporated into this calculation and verified during the technical review of this report, and are therefore rated as exempt software (PRC-PRO-IRM-309, Section 1.3, Exemptions).

5.2 APPROVED SOFTWARE

5.2.1 STOMP©

5.2.1.1 Description. Model simulations used STOMP© Build 4, approved for use by CHPRC at the Hanford Site in accordance with the requirements of PRC-PRO-IRM-309. The installed STOMP© software was tested in accordance with the procedure per CHPRC-00176.

Post-processing of STOMP© output was performed in part using the surfaceTo.pl, plotTo.pl, and outputTo.pl Perl scripts provided with STOMP© by Pacific Northwest National Laboratory and managed under CHPRC-00176. Additional post-processing was performed using FORTRAN codes and independently checked with Microsoft Excel®.

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

- Software Title: STOMP©
- Software Version: CHPRC Build 4 (executable "stomp-w-cgst-chprc04i.x")
- HISI Identification Number: 2471 (Safety Software, Level C)
- Workstation type and property number (from which software is run): STOMP© was executed on the INTERA Richland GREEN Linux® Cluster that is owned and managed by INTERA, Inc., a pre-selected subcontractor to CHPRC. The computer property tag for the front-end node is #469 at INTERA's office in Richland, Washington. This node is a Dell® PowerEdge® R510 with two 6-core Intel® Xeon X5660 processors @

†† Microsoft Excel is a registered product of the Microsoft Corporation.

2.80GHz and 48 GB of RAM. As given by the command "uname –a", the operating system details are: Linux green 3.2.0-65-generic #98-Ubuntu SMP Wed Jun 11 20:27:07 UTC 2014 x86_64 x86_64 x86_64 GNU/Linux.

5.2.1.2 Software Installation and Checkout. The software installation and checkout form for STOMP© is provided in Attachment 4 to this EMCF.

5.2.1.3 Statement of Valid Software Application.

- DOE/RL-2011-50 contains a summary of the main model attributes and code selection criteria that serve as the basis for the demonstration of the adequacy of the STOMP© code for use in vadose zone modeling at Hanford. The results of the evaluation in DOE/RL-2011-50 show that the STOMP© code is capable of meeting or exceeding the identified attributes and criteria. The comparison of the code selection criteria to the STOMP© code capabilities indicates the STOMP© code is capable of simulating all of the necessary Features, Events, and Processes (FEPS), and that STOMP© meets all of the other required code selection criteria. Section 6.4.1 of DOE/RL-2011-50 addresses code selection criteria, including quality assurance documentation of verification studies for specific model attributes (e.g., unsaturated flow, solute transport, infiltration, and drainage), and includes a discussion of other code related criteria (i.e., inter-code comparisons, hardware requirements, solution methodology, dimensionality, and output capability).

- The results of CHPRC acceptance testing (CHPRC-00515) demonstrate that the STOMP© software is acceptable for its intended use by the CHPRC. Installations of the software are operating correctly, as demonstrated by the INTERA Linux® Cluster system producing the same results as those presented for selected problems from the STOMP© application guide (PNNL-11216, "STOMP Subsurface Transport Over Multiple Phases: Application Guide,") in accordance with the software test plan (CHPRC-00211, "STOMP Software Test Plan").

- The methodology of this EMCF adapts STOMP© models already developed and reviewed for application to simulating similar scenarios at the same tank farms as part of the Final TC&WM EIS (DOE/EIS-0391). A major aspect of the adaptation of the STOMP© models for the pre-retrieval risk assessment is the addition and implementation of the saturated zone, which is within STOMP©'s capabilities and intended use for solving flow and transport problems in variably-saturated porous media.

- The pre-retrieval risk assessment used the "Water" operational mode of STOMP© within the software limitations because the contaminants simulated are non-volatile, transport is primarily in the aqueous phase, and there is no difference in the main assumptions implicit in the Final TC&WM EIS applications (e.g., thermal equilibrium, local chemical equilibrium, dilute aqueous concentrations for purposes of equilibrium calculations, no chemical reactions except radioactive decay and those represented by distribution coefficients). The "Courant" option is invoked in all transport simulations so that

STOMP© automatically constrains time steps to satisfy the Courant-Friedrichs-Lewy condition for numerical convergence (PNNL-15782).

5.2.2 MODFLOW and Related Codes Support Software

The effective hydraulic conductivity of the region of the aquifer included in the TWRWP STOMP© model domains was calculated from the CPGWM calibration version 3.3 (a MODFLOW-2000-MST application documented in CP-47631 Rev. 2, Model Package Report, Central Plateau Groundwater Model, Version 6.3.3) using the local values at steady state for the flux, hydraulic gradient, and saturated thickness. Model properties and steady-state results were visualized using Groundwater Vistas™ and ArcGIS™. Steady-state fluxes for selected regions were extracted from the CPGWM output using ZONEBUDGET (USGS Open-File Report 90-392).

CHPRC-00257, "MODFLOW and Related Codes Functional Requirements Document" distinguishes calculational software from supporting software because these two groups of software are classified and graded differently. The basis for the difference is that calculational software, including MODFLOW-2000-MST and MT3DMS-MST, calculate results that will be used to support decision-making and as such, constitute safety software graded to level C. In contrast, supporting software includes graphical interfaces, visualization, and input preparation support but not calculation of results that directly support decision-making, and are therefore not rated as safety software. The support software items identified in CHPRC-00258 and used in this calculation were:

- Groundwater Vistas™: ("Guide to Using Groundwater Vistas" [Rumbaugh and Rumbaugh 2007].) Used graphical tools for model output review. Groundwater Vistas™ was used in post-processing some output files from previously-documented CPGWM runs.

- ArcGIS™: (The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns and Relationships [Mitchell 1999].) Provided visualization tool for assessing and mapping CPGWM cell locations relative to facility coordinates. ArcGIS™ was used in post-processing previously-documented CPGWM simulation results.

- ZONEBUDGET: (USGS Open-File Report 90-392) Steady-state fluxes for selected regions were extracted from the previously-documented CPGWM output using ZONEBUDGET.

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6.0 CALCULATION

The steps outlined in Section 3, Methodology, were performed as follows.

6.1 DETERMINE PRIMARY INDICATOR CONTAMINANTS

The following percentage contributions to impacts were determined from the TC&WM EIS results.

Table 1a. Radionuclide Contributions to Peak Impacts at A Barrier Boundary from Tank Closure and Waste Management Environmental Impact Statement Alternative 2B Analysis.

Contaminant	Peak ILCR – Drinking-Water Well User	ILCR Contribution – Drinking-Water Well User	Peak ILCR – Resident Farmer	ILCR Contribution – Resident Farmer
Past Leaks				
Technetium-99	8.40×10^{-5}	97.7%	2.76×10^{-4}	98.9%
Iodine-129	1.76×10^{-6}	2.0%	2.73×10^{-6}	1.0%
Radionuclides Total	8.60×10^{-5}	100.0%	2.79×10^{-4}	100.0%
Retrieval Leaks				
Technetium-99	5.68×10^{-6}	91.5%	1.87×10^{-5}	95.9%
Iodine-129	5.26×10^{-7}	8.5%	8.13×10^{-7}	4.2%
Radionuclides Total	6.21×10^{-6}	100.0%	1.95×10^{-5}	100.0%
Tank Residuals				
Technetium-99	9.60×10^{-6}	97.7%	3.16×10^{-5}	99.1%
Iodine-129	2.28×10^{-7}	2.3%	3.52×10^{-7}	1.1%
Radionuclides Total	9.83×10^{-6}	100.0%	3.19×10^{-5}	100.0%
Ancillary Equipment Residuals				
Technetium-99	1.87×10^{-6}	94.0%	6.15×10^{-6}	97.2%
Iodine-129	1.19×10^{-7}	6.0%	1.84×10^{-7}	2.9%
Radionuclides Total	1.99×10^{-6}	100.0%	6.33×10^{-6}	100.0%

Notes:
[a] Results from Tables Q-69, Q-92, Q-100, and Q-108 in DOE/EIS-0391 Appendix Q
[b] ILCR = Incremental Lifetime Cancer Risk
[c] Constituent percentages may total greater than 100% due to rounding in source tables.

ILCR = Incremental Lifetime Cancer Risk
TC&WM EIS = DOE/EIS-0391, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

Table 1b. Non-Radiological Chemicals Contributions to Peak Impacts at A Barrier Boundary from Tank Closure and Waste Management Environmental Impact Statement Alternative 2B Analysis.

Contaminant	Peak HQ – Drinking-Water Well User	HQ Contribution – Drinking-Water Well User	Peak HQ – Resident Farmer	HQ Contribution – Resident Farmer
Past Leaks				
Chromium	6.26×10^{-1}	94.3%	6.49×10^{-1}	68.4%
Nitrate (as NO_3)	3.81×10^{-2}	5.7%	2.99×10^{-1}	31.5%
Chemicals Total	6.64×10^{-1}	100.0%	9.49×10^{-1}	100.0%
Retrieval Leaks				
Chromium	1.28×10^{-2}	18.4%	1.33×10^{-2}	2.9%
Nitrate (as NO_3)	5.69×10^{-2}	81.6%	4.47×10^{-1}	97.0%
Chemicals Total	6.97×10^{-2}	100.0%	4.61×10^{-1}	100.0%
Tank Residuals				
Chromium	5.16×10^{-2}	85.7%	4.61×10^{-2}	39.1%
Nitrate (as NO_3)	7.44×10^{-3}	12.4%	6.95×10^{-2}	58.9%
Chemicals Total	6.02×10^{-2}	100.0%	1.18×10^{-1}	100.0%
Ancillary Equipment Residuals				
Chromium	1.24×10^{-2}	80.5%	1.23×10^{-2}	32.4%
Nitrate (as NO_3)	2.97×10^{-3}	19.3%	2.56×10^{-2}	67.4%
Chemicals Total	1.54×10^{-2}	100.0%	3.80×10^{-2}	100.0%

Notes:

[a] Results from Tables Q-69, Q-92, Q-100, and Q-108 in DOE/EIS-0391 Appendix Q.

[b] HQ = Hazard Quotient.

[c] Constituent percentages may total greater than 100% due to rounding in source tables.

TC&WM EIS = DOE/EIS-0391, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

Chromium was the only contaminant contributing to non-radiological ILCR in the TC&WM EIS results at the time of peak groundwater impacts.

The indicator contaminants accounting for at least 95% of impacts in the TC&WM EIS analysis over the range of relevant source terms and exposure scenarios were ^{99}Tc, ^{129}I, chromium, and nitrate. Nitrite was retained in addition to nitrate because the DMT indicated a sensitivity to the nitrogen speciation assumption in the TC&WM EIS, and evaluating the assumption is non-trivial.

6.2 COMPILE RELEVANT STOMP© INPUT FILES FROM TC&WM EIS

Input files used in the final TC&WM EIS were transmitted May 29, 2013 on a CD ROM which has been copied to an internal network by INTERA, Inc. The directory "STOMP & Release to VZ input files\Preferred Alternative\" contains several subdirectories of which the following are relevant to the pre-retrieval risk assessment for WMA A/AX: 3TFrPLrc3\, 10ATFrAErc3\, 10BTFrTRrc3\, 10CTFrRLrc3\, 17TFcPLrc3\, 24ATFcAErc3\, 24BTFcTRrc3\, and 24CTFcRLrc3\. Following the first one to three characters in the directory name, the letters *TF* denote tank farm simulations, a lowercase *r* denotes radionuclides or a lowercase *c* denotes non-radiological chemicals, and the next two letters denote the type of source term (*PL* for past leaks, *AE* for ancillary equipment residuals, *TR* for tank residuals, and *RL* for retrieval leaks). Within each of these subdirectories are further subdirectories for each tank farm, with "TF_A\" containing input files for A Farm and "TF_AX\" containing input files for AX Farm. The STOMP© input files were saved with the extension .INP and filenames including either the word *FLOW* for the initial historical flow field simulation or the name of a contaminant (e.g., *C-14* for radiocarbon) for each predictive flow and contaminant transport simulation.

One additional file saved with the extension .INP is an input file for the "Release to Vadose Zone" code containing instructions used by that code to write the included STOMP© input files. The "Release to Vadose Zone" code was not re-run, but the "SCENARIO AND SOURCE TERM DATA" sections of the input files were referenced to confirm the intended locations, years, and total inventories of simulated releases.

To execute a STOMP© simulation, the input file must be renamed "input" (with no extension), so a copy of each relevant file was placed in its own separate working directory identifying the simulation. The FLOW simulations for each tank farm generate restart files as output, and the last of these files (corresponding to 3,000 years of initial flow field development) is used to specify the initial conditions in 1940 for the predictive flow and transport simulations. So after running the FLOW simulations, a copy of the relevant restart file is similarly renamed "restart" and placed in the subdirectory with the input file for each predictive simulation.

As described in the next steps, modifications were made to the STOMP© model grids and other input for A Farm and AX Farm and the changes were copied into each input file. An input file with a single source release term combining retrieval leaks from all four AX-100-series tanks was broken into four input files to separately simulate a retrieval leak from each AX-100-series tank. Source release terms and contaminant-specific parameters for selected indicator contaminants were copied from multiple input files for each scenario into a single input file for a combined simulation of either radionuclides or non-radiological chemicals. Source release terms and model parameters for nitrite are calculated in later steps based on inputs for the nitrate simulations. Names of the working directories followed similar nomenclature to the TC&WM EIS directories and input files.

Note that the final STOMP© input files for the TWRWP model differ in layout from the TC&WM EIS input files due to addition and deletion of some large segments of code, re-ordering the cards to make relatively short cards easier to locate, and insertion of comment lines to improve readability or label certain features. Comment lines include extended header sections

tracing the changes from the TC&WM EIS files to assist the calculation Checker in understanding whether any given section of code was existing, modified, or new.

6.3 SELECT CURRENT BUILD OF STOMP© AND ADJUST INPUT FILES FOR CONSISTENCY WITH TANK CLOSURE AND WASTE MANAGEMENT ENVIRONMENTAL IMPACT STATEMENT

The STOMP© executable selected from the currently approved set is stomp-w-cgst-chprc04i.x (CHPRC-00176). This is Build 4 of the STOMP© code released for use by CH2M Hill Plateau Remediation Company for the Water operational mode with the SPLIB conjugate gradient stabilized solver in the Linux operating system using the Intel Fortran compiler.

The only difference with respect to input format from the earlier build used for the TC&WM EIS that required adjustment to input is the inclusion of new options for the method of specifying matrix compressibility via the Mechanical Properties Card. Consistency with the TC&WM EIS simulations with respect to matrix compressibility was favored absent a compelling reason to change methods. Formerly, the only method used pore compressibility with a specific storativity of 10^{-7} Pa^{-1}, and it is now necessary to specify that option to avoid defaulting to a different method. The instruction was inserted for every material type.

6.4 LOCATE VERTICAL REFERENCE POINTS FOR STOMP© MODEL GRIDS

To adapt the TC&WM EIS STOMP©-based models of the vadose zone to include the saturated zone, available engineering drawings are used to establish the location of the selected water table elevation relative to contaminant sources in each model, and plots of the distribution of materials in the vadose zone are compared to understand the alignment of the A Farm and AX Farm models to each other.

The ground surface elevation is 680.67 ft at tanks AX-101 and AX-103 and 681.67 ft at tanks AX-102 and AX-104 (SD-WM-TI-356, "Waste Storage Tank Status and Leak Detection Criteria," drawing 11-00-01). The datum of drawing 11-00-01 is inferred to be the National Geodetic Vertical Datum of 1929 (NGVD 29) based on the comparable approximate ground surface elevation of 680 ft indicated in a 1963 drawing (Figure 3 in HW-79805, "Geology Underlying the 241-AX Tank Farm"). The elevation at the inside base of the AX-100-series tanks is 628.42 ft NGVD 29 (SD-WM-TI-356 pp. 11-00-01). SD-WM-TI-356 pp. 11-00-01 indicates the base of the tank below 628.42 ft NGVD 29 comprises a 3/8-inch-thick plate, on top of 18 inches of concrete, on top of 2 inches of grout, allowing estimation of the bottom of the AX tanks elevation as follows:

$$Bottom\ of\ AX\ tanks\ elevation\ (ft\ NGVD\ 29) = 628.42\ ft\ NGVD\ 29 - \left(\frac{3}{8}in. + 18in. + 2in.\right)\frac{1ft}{12in.}$$

$$Bottom\ of\ AX\ tanks\ elevation\ (ft\ NGVD\ 29) = 626.72\ \text{ft NGVD 29}$$

Within the combined lateral domains of the A Farm and AX Farm models, elevations on the NGVD 29 datum are adjusted to the NAVD 88 datum by adding 1.064 m, a value calculated using Corpscon 6.0.1 (Army Geospatial Center, United States Army Corps of Engineers, Queried 05/19/2015, [Corpscon 6.0.1], http://www.agc.army.mil/Missions/Corpscon.aspx) and verified within 0.2 m using a published map (VERTCON – North American Vertical Datum Conversion, National Geodetic Survey, Queried 05/19/2015, [VERTCON, NAVD 88 minus NGVD 29 Datum Shift Contours], http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html). Using a conversion factor of 0.3048 m/ft, the bottom of the tank elevation was converted as follows:

$$Bottom\ of\ AX\ tanks\ elevation\ (m\ NAVD\ 88) = (626.72\ \text{ft NGVD 29})\left(\frac{0.3048m}{ft}\right) + 1.064\ m$$

$$Bottom\ of\ AX\ tanks\ elevation\ (m\ NAVD\ 88) = 192.1\ m\ NAVD\ 88$$

The distance from the bottom of the tanks to the steady-state water table is estimated as follows:

$$Bottom\ of\ AX\ tanks\ to\ water\ table = 192.1\ m\ NAVD\ 88 - 119.5\ m\ NAVD\ 88$$

$$Bottom\ of\ AX\ tanks\ to\ water\ table = 72.6\ m$$

The TC&WM EIS AX Farm STOMP© input files for past leaks, retrieval leaks, and tank residuals simulate releases from the bases of the AX tanks at the 36th *k* node index, or 72 m above the base of the model domain, which was intended to correspond to the water table. Within the STOMP© model discretization (2-m vertical spacing), the water table is already located at the correct depth to apply the assumption of the CPGWM steady state water table elevation. Therefore the saturated zone for the AX model may simply be built underneath the existing vadose zone grid.

The total depth to the steady-state water table (DTW) is calculated by subtracting the water level elevation (WLE) from ground surface (GS) as follows:

$$DTW(m) = GS(m\ NAVD\ 88) - WLE(m\ NAVD\ 88)$$

For AX Farm, both available ground surface values give DTW of roughly 89 m:

$$DTW = (680.67ft\ NGVD\ 29)\left(0.3048\frac{m}{ft}\right) + 1.064m - 119.5m\ NAVD\ 88 = 89.0m$$

Or

$$DTW = (681.67ft\ NGVD\ 29)\left(0.3048\frac{m}{ft}\right) + 1.064m - 119.5m\ NAVD\ 88 = 89.3m$$

The TC&WM EIS AX Farm STOMP© input files for residuals in ancillary equipment simulate releases at the 39th k node index, or 6 m above the base of the AX Farm tanks. SD-WM-TI-356 pp. 11-00-01 indicates the fill lines and spare lines connecting ancillary equipment to the AX Farm SSTs are 32 ft 4 in. (9.86 m) above the plates at the inside bases of the tanks. Presuming that most of the pipelines are at or shallower than the elevation of the fill lines, the

releases from ancillary equipment may be conservatively simulated a few meters deeper than necessary. However, the difference is too small relative to the implemented transport distance of 78 m to the water table to justify the effort required to revise the release elevation at this time. The authors are not aware of any analysis of the full distribution of probable depths of residuals in ancillary equipment in WMA A/AX having been completed since the TC&WM EIS, and accounting for the elevations of all the numerous pipelines and the ancillary equipment other than pipelines is beyond the scope of this calculation. Also, extending the STOMP© domains further upward much beyond the fill line elevation would require new parameterization of the shallow vadose zone with accompanying research and documentation.

Drawing No. H-2-31880 provides elevations near the A Farm tanks. Leak detection lateral lines underneath the SSTs tie into vertical caissons between the SSTs. Ground surface elevations are indicated as 1 ft below curb elevations of 690.0 ft at Caisson No. 1 and 688.0 ft at Caisson No. 2. The datum is inferred to be NGVD 29 based on the last drawing update being dated 1968. Hence the ground surface elevation is estimated from the average curb elevation as follows:

$$A\ Farm\ GS\ (m\ NAVD\ 88) = (689.0\ ft\ NGVD\ 29 - 1\ ft)\left(0.3048\frac{m}{ft}\right) + 1.064\ m$$

$$A\ Farm\ GS = 210.8\ m\ NAVD\ 88$$

The total DTW is estimated as follows:

$$A\ Farm\ DTW = 210.8\ m\ NAVD\ 88 - 119.5\ m\ NAVD\ 88 = 91.3\ m$$

Center line elevations (CLEs) of lateral lines beneath each SST are listed in H-2-31880 as 626.59 ft for A-101, 625.88 ft for A-102 and A-104, 624.88 ft for A-103 and A-105, and 623.59 ft for A-106. The minimum and maximum of these lateral line elevations are converted as follows:

$$min\ CLE = (623.59ft\ NGVD\ 29)\left(0.3048\frac{m}{ft}\right) + 1.064m = 191.13\ m\ NAVD\ 88$$

$$max\ CLE = (626.59ft\ NGVD\ 29)\left(0.3048\frac{m}{ft}\right) + 1.064m = 192.05\ m\ NAVD\ 88$$

Estimating the bottoms of the A-100-series SSTs to be nominally 2 to 3 m above the sloping lateral lines, the tank bottom elevations range from about 193 m NAVD 88 to 195 m NAVD 88. The distance from the bottom of the tanks to the steady-state water table is estimated from the middle of this range follows:

$$Bottom\ of\ A\ tanks\ to\ water\ table = 194\ m\ NAVD\ 88 - 119.5\ m\ NAVD\ 88$$

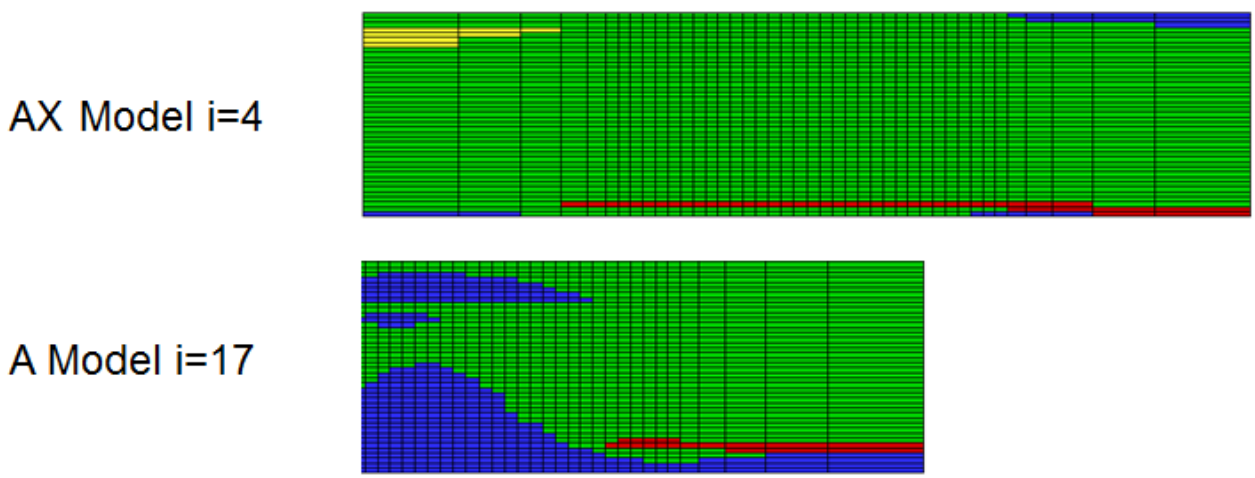
$$Bottom\ of\ A\ tanks\ to\ water\ table = 74.5\ m$$

The TC&WM EIS A Farm STOMP© input files for past leaks, retrieval leaks, and tank residuals simulate releases from the bases of the A tanks at the 40th *k* node index, or 80 m above the base

of the model domain, which was intended to correspond to the water table. Without changing the 2-m vertical spacing, this implies 3 extra layers of k nodes which either place the steady state water table too deep for the CPGWM value or the bases of the A Farm tanks too shallow. Consistent with this estimate, the *k* node index of the bases of the A Farm tanks is higher than the *k* node index of the base of the AX Farm tanks by 4 when it should be higher by only 1.

To clarify the reason for the difference and the appropriate adjustment necessary to build consistent saturated zones in the A Farm and AX Farm models while maintaining consistent vadose zone representations, the existing TC&WM EIS vadose zone models were run to generate plot files which were post-processed with plotTo.pl and viewed in TecPlot to visualize and compare the rock/soil zonation. As an example of the broader comparison visualized in three dimensions, selected cross-sectional comparisons of the closest node indices between the two models are shown in the following figures with the overlapping portion approximately aligned horizontally. The rock/soil zones used in the TC&WM EIS vadose zone models are shown as follows: the "Alluvium" HSU in orange, the "HanfordGravel" HSU in blue, the "HanfordSand" HSU in Green, the "HanfordSilt" HSU in yellow, and the "HanfordMud" HSU in red. The distinction between the "Alluvium" and "HanfordSand" HSU materials is irrelevant given their identical hydraulic properties (see Table N-1 in DOE/EIS-0391 Appendix N). The two models' granularity and different discretizations of the overlapping portion of their domains means that it was not possible for the models to have exactly the same representation of the vadose zone, but generally both models are dominated by sand and gravel materials that provide rapid transport relative to the small proportion of "HanfordMud" HSU material occurring near the base of each model. The "HanfordMud" HSU thus has the largest influence on total transport times.

Figure 9a. First Example Comparison of Nearby Cross-Sections from Tank Closure and Waste Management Environmental Impact Statement STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment.



The "HanfordMud" HSU has hydraulic properties typical of clay which give it the strongest contrast with the other rock/soil zones (see Table N-1 in DOE/EIS-0391 Appendix N). The "HanfordMud" HSU in the A Farm and AX Farm models occurs as a discrete zone near the base of the vadose zone which serves as a convenient marker to check the vertical alignment of the model domains. Note that the cross-section segments in Figures 9a through 9d are chosen

because they include the "HanfordMud" HSU to use as a marker, but the "HanfordMud" HSU is absent in most of the A Farm domain south and east of the figure locations.

Figure 9b. Second Example Comparison of Nearby Cross-Sections from Tank Closure and Waste Management Environmental Impact Statement STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment.

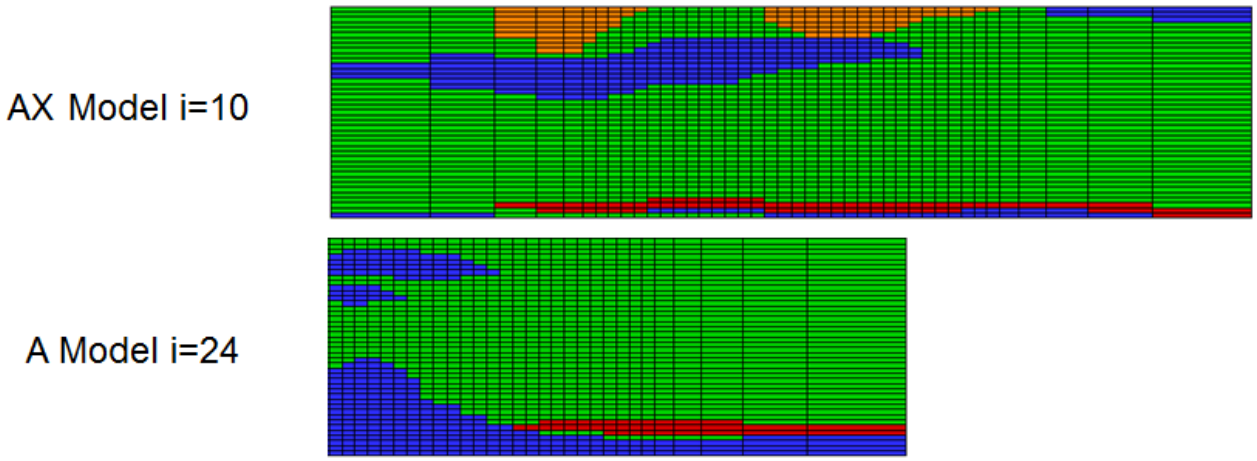
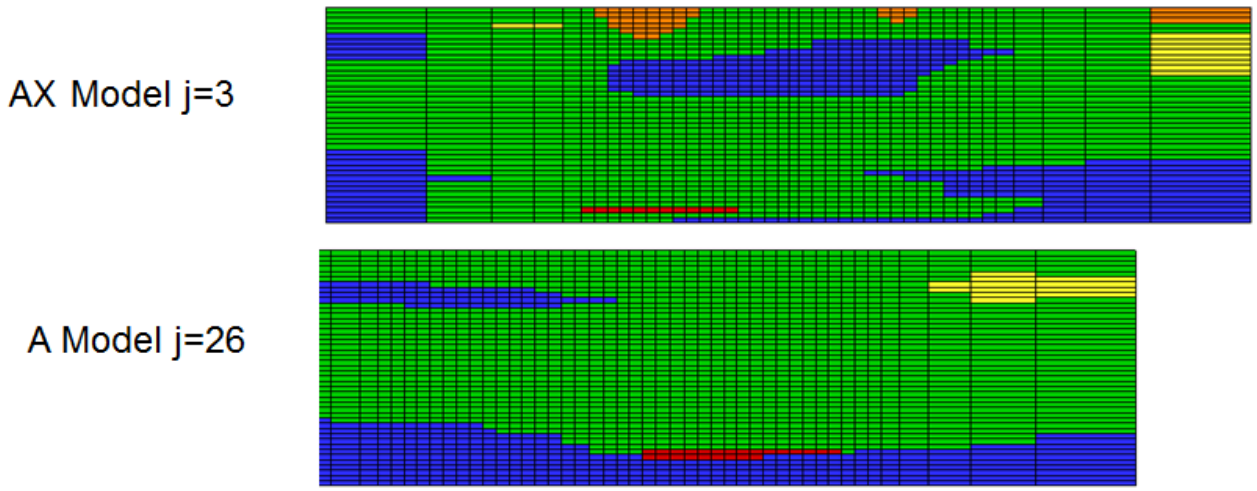


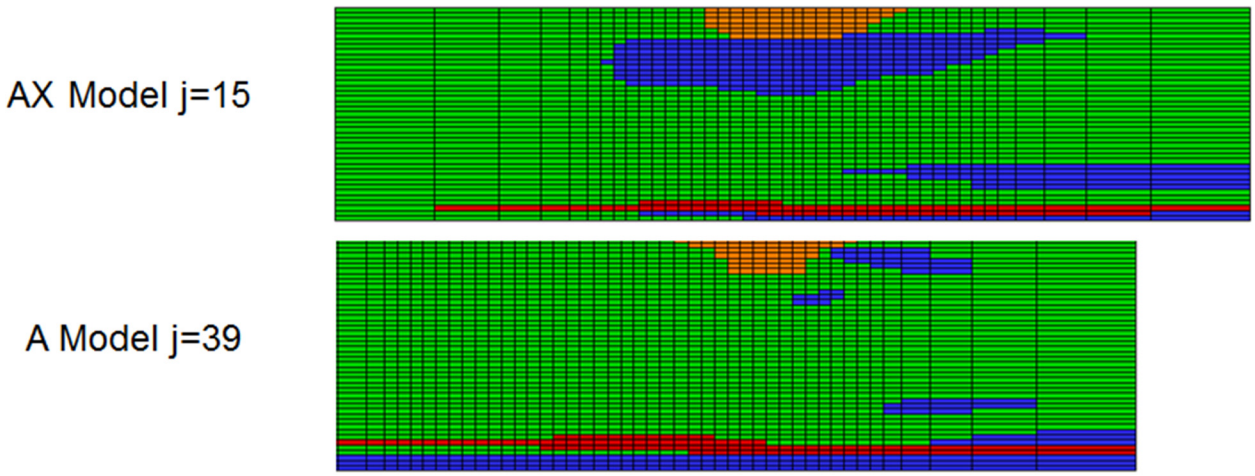
Figure 9c. Third Example Comparison of Nearby Cross-Sections from Tank Closure and Waste Management Environmental Impact Statement STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment.



Visual comparison of the location of the red "HanfordMud" HSU in the approximately equivalent cross-sections shows that the A Farm model typically has an additional 3 layers (at 2-m spacing) of the "HanfordGravel" HSU at the base of its domain below the "HanfordMud" HSU versus the AX Farm model, confirming that the A Farm model layers that would be "extra" for the vadose zone are simply gravels that lie below the steady state water table elevation from the CPGWM calibration. Therefore, to implement the saturated zone, the bottom 6 meters of the

A Farm model can be re-discretized and re-parameterized, and additional layers can be added underneath.

Figure 9d. Fourth Example Comparison of Nearby Cross-Sections from TC&WM EIS STOMP© Grids for A Farm and AX Farm Models to Establish Vertical Alignment.



The TC&WM EIS A Farm STOMP© input files for residuals in ancillary equipment simulate releases at the 43rd *k* node index, or 6 m above the base of the A Farm tanks. As with the AX Farm tanks, these releases may be conservatively simulated a few meters deeper than necessary, but the difference is too minor to justify a revision at this time.

6.5 EXTEND STOMP© MODEL GRIDS FOR EACH TANK FARM DOWNWARD INTO SATURATED ZONE

To represent the upper portion of the saturated zone including the average steady-state saturated thickness of the higher-conductivity gravel present below the water table, the AX Farm model grid was extended 11 m downward by adding 11 layers at 1-m spacing. The A Farm model grid included 6 m below the water table elevation to be used in the pre-retrieval risk assessment, so it was extended 5 m downward by subdividing the bottom 3 layers with 2-m spacing into 6 layers at 1-m spacing and adding 5 new layers below at 1-m spacing. The changes are implemented in the STOMP© input file by specifying more nodes and new spacing for the *k* index (used for the vertical *z*-dimension) in the Grid Card and adding the appropriate number (11 for AX Farm or 8 for A Farm) to all *k* indices in other input cards (vertical numbering is from the base of the model upward).

The number and spacing of nodes for the *i* and *j* indices (used in these models for the east-west *x*-direction and the north-south *y*-direction, respectively) are unchanged, so the horizontal grid design for the new saturated zone layers is the same as for the existing vadose zone layers. This means the aquifer area of each model grid underlying the tank farm of interest for that grid plus the nearest sections of the fence line is discretized with rectangular cells 1-m thick and 4- to 5.5-m on a side (rows and columns containing tanks have 5-m spacing whereas rows and columns between tanks have slightly different spacing). More distant sections of the fence line

that are not directly downgradient of the source areas overlie grid cells with side lengths increasing harmonically up to the maximum spacing of 38 m for the rows and columns at the edges of the domain, and a small portion of the fence line south of A Farm lies outside the AX Farm model domain (see Figures 4 and 5).

In summary, the typical grid discretization for a location where groundwater concentrations are to be calculated (the 5-m vertical interval below the water table at the downgradient fence line) is a stack of 5 cells (*k* indices 7 through 11) of 1-m height and 5-m length on each side.

6.6 ASSIGN AQUIFER PARAMETERS

In the Rock/Soil Zonation Card for STOMP© (PNNL-15782), a new rock/soil zone "Aquifer" is declared in order to assign properties to layers 1 through 11 which represent the upper saturated zone in each model grid. All aquifer properties are assigned uniform values over the model domains. The designations of rock/soil zonation for the 3 layers formerly at the base of the A Farm model were deleted and a single line of input designates the bottom 11 layers as "Aquifer."

In the following discussion, note that some unused parameters were deleted from the final TWRWP model input files for clarity. The TC&WM EIS input files contained copies of master lists of parameters for several HSU material types that are relevant only if they occur in the vadose zone in a given model grid. Many of the HSU material types were not present in A Farm or AX Farm model domains according to the existing Rock/Soil Zonation Cards, so they were deleted. If a reference is made to a deleted HSU material type, consult the TC&WM EIS input file.

In the Mechanical Properties Card for STOMP© (PNNL-15782), a line was inserted assigning "Aquifer" the same parameters as the other HSU material types except that total porosity and diffusive porosity are each assigned a value of 0.2 (RPP-14430, Section 2.4.2.4).

In the Hydraulic Properties Card for STOMP© (PNNL-15782), a line was inserted assigning "Aquifer" hydraulic conductivity values of 1750 m/d in the x- and y-directions and 175 m/d in the z-direction based on the local-scale effective hydraulic conductivity (for the upper 11 m of the saturated zone over the combined domains of the A Farm and AX Farm models) derived from the CPGWM calibration Version 3.3 local steady-state flux and hydraulic gradient.

STOMP© requires parameters for each HSU material declared in the Rock/Soil Zonation Card (PNNL-15782), including relative permeability parameters which for the saturated zone are not intended to affect results. In the Saturation Function Card for STOMP© (PNNL-15782), a line was inserted assigning "Aquifer" van Genuchten parameters (van Genuchten, 1980) that were specified for the "ColdCreekGravel" HSU material in the TC&WM EIS input files. In the Aqueous Relative Permeability Card for STOMP© (PNNL-15782), a line was inserted specifying the Mualem method (Mualem 1976) for "Aquifer" as used for the other HSU material types.

In the Solute/Porous Media Interaction Card for STOMP© (PNNL-15782), a line was inserted assigning "Aquifer" a longitudinal dispersivity of 1 m and a transverse dispersivity of 0.1 m, based on the minimum lateral distance between sources at SSTs and the WMA fence line of approximately 10 m (see Section 4).

Also in the Solute/Porous Media Interaction Card for STOMP©, distribution coefficients (K_d values) were assigned to "Aquifer" for each contaminant using the same values for all geologic media in the vadose zone and saturated zone. K_d values are zero for all the reported indicator contaminants as in the TC&WM EIS input files, but some TWRWP model input files may contain non-zero values for other contaminants examined in preliminary runs. The K_d value of zero for nitrite was used with past DMT analyses (see DOE/ORP-2005-01 Tables 3-7 and 3-8).

6.7 ASSIGN BOUNDARY CONDITIONS AND INITIAL CONDITIONS

All saturated zone boundary conditions are calculated in Attachment 1, including formatting for STOMP© input instructions which were subsequently edited to include appropriate line breaks and numbers of commas for delimiting solute boundary conditions as applicable. Other changes listed in Section 3.7 were implemented directly in STOMP© input files.

The main elements of boundary condition calculations performed in Attachment 1 (retaining extra digits of precision to avoid round-off errors in model inputs) are as follows. The pressure of the elevation of the bottommost node in the SE corner of each model domain was calculated as follows:

$$P_{k=1} = 101{,}325\ Pa + \left(-9793.5192\frac{Pa}{m}\right)\left[(108.5\ m\ NAVD\ 88) + \frac{(1\ m)}{2} - (119.5\ m\ NAVD\ 88)\right]$$

$$P_{k=1} = 204{,}156.95\ Pa$$

The x-component of the hydraulic gradient (i_x) and the y-component of the hydraulic gradient (i_y) are calculated as follows:

$$i_x = 1 \times 10^{-5}[-\cos(45\ degrees)] = -7.07107 \times 10^{-6}$$

$$i_y = 1 \times 10^{-5}[\sin(45\ degrees)] = 7.07107 \times 10^{-6}$$

The prescribed flux (q_x) into the saturated zone along the entire length of each tank farm model's western domain boundary is calculated as follows:

$$q_x = -K \times i_x = -\left(1750\frac{m}{d}\right)\left(365.2425\frac{d}{yr}\right)(-7.07107 \times 10^{-6})$$

$$q_x = 4.51965\frac{m}{yr}$$

The prescribed flux (q_y) into the saturated zone along the entire length of each tank farm model's northern domain boundary is calculated as follows:

$$q_y = -K \times i_y = -\left(1750\frac{m}{d}\right)\left(365.2425\frac{d}{yr}\right)(7.07107 \times 10^{-6})$$

$$q_y = -4.51965\frac{m}{yr}$$

Prescribed head boundary conditions are imposed using the hydraulic gradient components to calculate pressures at node positions relative to the SE corner as described in Section 3.7.

6.8 MODIFY TIME-STEPPING TO ACCOMMODATE SATURATED ZONE ADVECTION

The maximum time step was reduced to 1 year in the Solution Control Card for STOMP© (PNNL-15782) for predictive flow and transport simulations, the "Courant" option was retained, and the maximum iterations limits were increased as noted in Section 3.8.

6.9 ASSIGN ANY TRANSPORT PARAMETERS FOR INDICATOR CONTAMINANTS NOT SPECIFIED IN THE TC&WM EIS

The only additional indicator contaminant to those identified from the TC&WM EIS was nitrite, which did not have parameters specified by the TC&WM EIS analysis.

A K_d value of zero consistent with the DMT was specified in the Solute/Porous Media Interaction Card for STOMP©.

In the Solute/Fluid Interaction Card for STOMP©, the aqueous-phase molecular diffusion coefficient for nitrite (NO_2) was specified using the following estimate from the value for nitrate (NO_3):

$$D_{w,NO2} \cong D_{w,NO3} \times \sqrt{\frac{m_{NO3}}{m_{NO2}}} = \left(6.0 \times 10^{-2}\frac{m^2}{yr}\right) \times \sqrt{\frac{62.0049 g/mole}{46.0055 g/mole}}$$

$$D_{w,NO2} \cong 7.0 \times 10^{-2}\frac{m^2}{yr}$$

Nitrite was specified as effectively non-decaying by assigning an arbitrarily large half-life of 1×10^{38} years in the Solute/Fluid Interaction Card for STOMP©.

6.10 POPULATE SOURCE RELEASE TERMS OF INDICATOR CONTAMINANT INVENTORIES AND VOLUMES

6.10.1 Past Releases

Past releases source release terms were unchanged from the TC&WM EIS input files except for adjusting k indices, re-calculation of nitrite and nitrate terms in Attachment 2, and correction of a transcription error in the AX Farm indices for past releases of non-radiological chemicals (the transcription error did not affect any results reported in the TC&WM EIS).

6.10.2 Retrieval Leaks

As shown in Attachment 2 (retaining extra digits of precision to avoid round-off errors in model inputs), the unit inventory solute release rate for a retrieval leak over a 16-node tank footprint over 1 year for AX Farm source release terms is 1.98051×10^{-9} Ci/s or kg/s. The water release rate for 4,000 gallons is 2.99881×10^{-8} m^3/s. The A Farm retrieval leaks source terms were unchanged from the TC&WM EIS input files except for adjusting k indices and re-calculation of nitrite and nitrate terms in Attachment 2.

6.10.3 Tank Residuals

Tank residuals source terms were unchanged from the TC&WM EIS input files except for adjusting *k* indices and re-calculation of nitrite and nitrate terms in Attachment 2.

6.10.4 Ancillary Equipment Residuals

Ancillary equipment residuals source terms were unchanged from the TC&WM EIS input files except for adjusting k indices and re-calculation of nitrite and nitrate terms in Attachment 2.

6.11 SPECIFY OUTPUT OF FENCE LINE WATER AND SOLUTE FLUXES ACROSS SURFACES FOR REPORTING IN THE SURFACE FLUX CARD

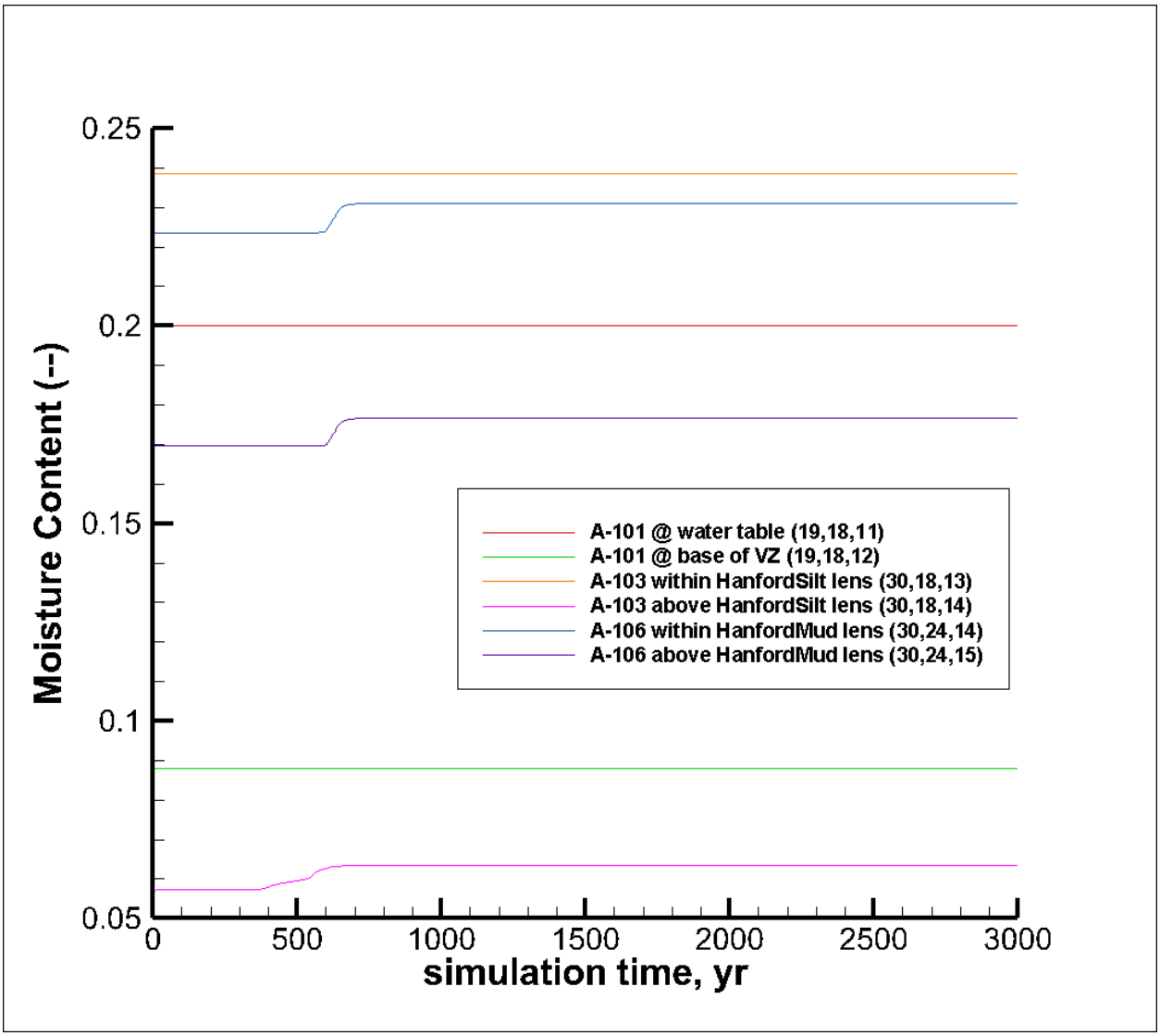
Fence line *i* and *j* node indices for each model grid were exported from ArcGIS and verified by visually counting nodes using Figures 4 and 5. Solute and water fluxes from *k* nodes 7 to 11 at each of these *i* and *j* locations were specified and grouped into surface files to organize output. A list of such instructions in the Surface Flux Card for STOMP© was copied from a template for the appropriate solutes into each input file to avoid transcription errors.

6.12 RUN HISTORICAL SIMULATIONS IN STOMP© MODELS TO OBTAIN INITIAL CONDITIONS FOR CALENDAR YEAR 1940 AND CONFIRM STEADY STATE MOISTURE CONDITIONS

The historical flow simulations were run with the STOMP© executable selected in Step 3. The AX Farm and A Farm STOMP© models each attained steady-state conditions within the

3,000-year period of historical flow simulation. An example of confirmation of stable moisture conditions for the A Farm model is shown in Figure 10.

Figure 10. Moisture Content at Selected Nodes of A Farm TWRWP Model Over Historical Simulation Period.



6.13 RUN PREDICTIVE SIMULATIONS IN STOMP© MODELS TO OBTAIN FENCE LINE WATER AND SOLUTE FLUXES

The predictive flow and transport simulations described in previous steps are run with the STOMP© executable selected in Step 3 and the restart files generated at the end of the historical flow simulations.

6.14 CONVERT FENCE LINE WATER AND SOLUTE FLUXES TO FENCE LINE GROUNDWATER CONCENTRATIONS AND DETERMINE THE TIME AND LOCATION OF PEAK IMPACT OF EACH INDICATOR CONTAMINANT FOR EACH SIMULATION

Solute fluxes and water fluxes into a 5-m interval below the water table were both output at every time step for each specified node along the fence line (or group of nodes where solute flux is expected to be zero as in upgradient locations). Within the resolution of each STOMP© model grid, groundwater concentrations of each indicator contaminant were calculated at every point along the downgradient fence line at every time step.

Post-processing of STOMP© output was performed with the surfaceTo.pl Perl script provided by the STOMP© authors and with FORTRAN codes that were verified during the technical review of this report with independent Microsoft Excel® post-processing, as noted in Section 5.2.1.1.

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7.0 RESULTS/CONCLUSIONS

The methodology developed for evaluating impacts for the groundwater pathway is largely based on local-scale modeling tools (with some modification) that were developed for the A and AX tank farms to support the TC&WM EIS. As such, reviewers of the results that follow should be cognizant of the following assumptions and aspects of the methodology developed to support this TWRWP, especially if comparing results of past or future modeling efforts:

- Points of Analysis – Per requirements outlined in the Consent Decree, results summarized here are provided at the WMA fence line which is hundreds of meters closer to the source areas (e.g., only 10 m from tanks AX-101 and AX-102) than the A Barrier Boundary where groundwater impacts from the WMA A/AX and other tank farm areas were evaluated in the TC-WM EIS. The WMA fence line is also closer to the source areas than points of analysis (i.e., 100 m downgradient of the WMA fence line) that will eventually be considered in the long-term performance assessment of a closed WMA A/AX. The TWRWP relies on the present day fence line rather than assume a location for a future fence line encompassing a closed WMA A/AX with a surface barrier. It is probable a future fence line would be further from the tanks than the present fence line. The location of the point of analysis affects the amount of dilution and dispersion that occur along the transport pathway.

- Model resolution – To facilitate the calculation of contaminant impacts at the WMA fence line the STOMP©-based local-scale models of the A and AX tank farm areas were extended into the underlying unconfined aquifer system. The grid resolution of this part of the local-scale models is highly discretized so that impacts can be examined at the WMA fence line, i.e., concentrations are typically determined in 5 m × 5 m × 5 m volumes, in contrast to the coarser resolution in the regional-scale model used to simulate transport of groundwater impacts from source areas to the A Barrier Boundary as applied in the TC&WM EIS.

- Past Leak Inventories – This analysis uses estimates of past leak inventories used in the TC&WM EIS. Recently updated estimates of past releases documented in RPP-RPT-58291, "Hanford Waste Management Area A-AX Soil Contamination Inventory Estimates," provide information for consideration in the WMA A/AX performance assessment that may produce changes in the location, timing, and magnitude of predicted past releases impacts.

- Retrieval Leak Inventories – This analysis includes updated information on potential retrieval leak inventories for the AX farm tanks (RPP-RPT-58867) while using existing estimates from the TC&WM EIS for retrieval leak inventories for the A Farm tanks. The A Farm tanks are expected to be retrieved in accordance with a future TWRWP(s) in which assumptions may be updated (for instance, tanks A-104 and A-105 are unlikely to be sluiced in light of past leaks). The approach for estimating retrieval leak inventories for the AX Farm tanks as documented in RPP-RPT-58867 differs from previous assessments.

- Residual Inventories – This analysis uses estimates of residual waste inventories in tanks and ancillary equipment used in the TC&WM EIS. Recently updated estimates of residual inventories documented in RPP-RPT-58293, "Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates," provide information for consideration in the WMA A/AX performance assessment that may produce changes in the location, timing, and magnitude of predicted residual inventory impacts. Residual inventories used in a final closure performance assessment will eventually be developed based on laboratory analysis of tank waste retrieval samples collected after the retrieval process at the WMA A/AX is completed.

- Contaminant Release Models for Residual Wastes – This analysis makes use of contaminant release models used for tank waste residuals in the TC&WM EIS. Release of source terms for residual waste from tanks and ancillary equipment were each based on the use of a partitioning-limited, convective-flow release model assumed for grout-stabilized waste (DOE/EIS-0391 Appendix M). Other recent tank farm assessments are evaluating the potential effects of the tank structure, grout in-filling of tanks, and the tank residuals in controlling the release of contaminants after closure. These assessments are considering diffusion-controlled and/or solubility-controlled release models for tank residuals that will generally limit contaminant releases from residual wastes and predict lower peak concentrations that would arrive later in time.

The indicator contaminants identified from results of the TC&WM EIS, the DMT, and preliminary runs of the present TWRWP model were ^{99}Tc, ^{129}I, chromium (Cr), nitrite (NO_2), and nitrate (NO_3).

The TC&WM EIS results indicate the only contributors to total WMA A/AX radiological ILCR at the fence line at the time of peak concentration would be the long-lived and highly mobile radionuclides, ^{99}Tc and ^{129}I, with ^{99}Tc being the major contributor. Technetium-99 was predicted to contribute greater than 90% of the total radiological ILCR for every source term and receptor scenario, and ^{99}Tc and ^{129}I combined contribute greater than 98%. For modeling purposes, highly mobile contaminants are those with distribution coefficient (K_d) values of 0 mL/g in the vadose zone and saturated zone sediments, as assumed in the TC&WM EIS. The contribution from ^{129}I and absence of carbon-14 (^{14}C) at the time of peak are due to the updated K_d values assumed in the TC&WM EIS (0 and 4.0 mL/g, respectively) versus the older values in the DMT (0.2 and 0 mL/g, respectively). Even with the treatment of ^{14}C as both non-reactive (except for radioactive decay) and non-sorbing in the DMT, it contributes less than 2% for every source term and receptor scenario. Tritium is too short-lived to contribute at the time of peak impact. Technetium-99 and ^{129}I were therefore selected as the radiological ILCR indicator contaminants for this evaluation.

The TC&WM EIS and DMT results indicate the only contributors to the total WMA A/AX noncarcinogenic chemical HI at the fence line at the time of peak would be the following highly mobile (K_d = 0 mL/g) chemicals: chromium, nitrite, and nitrate, with chromium and nitrite being the major drivers. From the TC&WM EIS results in which nitrite is accounted for as nitrate, these three chemicals combined were predicted to contribute at least 98% of the total HI for every source term and receptor scenario. Relative contaminant contributions could not be

accurately predicted from the TC&WM EIS results prior to recalculating separate nitrate and nitrite source terms, but since no chemical dominated the HI in every case, each was potentially significant. The analysis conservatively assumed that all chromium inventory was hexavalent chromium. The DMT indicated a contribution in past leaks scenarios from 1-butanol (n-butyl alcohol), however the TC&WM EIS updated K_d value of 3.0 mL/g eliminated the impact that arose from the DMT using a value of 0 mL/g. Chromium, nitrite, and nitrate were therefore selected as the noncarcinogenic chemical HI indicator contaminants for this evaluation.

Uranium was simulated as a moderately mobile (K_d = 0.6 mL/g) contaminant in the TC&WM EIS, and the results indicated uranium became the dominant radiological and chemical dose after calendar year 5000, but did not exceed the ILCR or HI of the mobile contaminants during the modeling period. A limited number of simulations of additional contaminants, including uranium, with the TWRWP model produced similar results. A potential retrieval leak from AX-102, which was estimated to have the highest uranium inventory of potential retrieval leaks from AX-100-series tanks and was nearest to the fence, produced a peak concentration of about 3×10^{-3} mg/L. Assuming essentially all of the mass was uranium-238, the resulting peak concentration would correspond to a radiological ILCR of about 2×10^{-6} and to a HQ of about 0.3, less than the peak values for mobile contaminants that are reported in RPP-CALC-60498. Contaminants with K_d values of 2.5 mL/g and higher did not break through to the water table during the 10,000-yr modeling period. Tritium peaked early at levels well below those of the other mobile contaminants and decayed to insignificant levels at the time of peak. The results confirmed the expectation, based on the TC&WM EIS, that peak impacts for the identified indicator contaminants comprise the peak impacts for the period of analysis overall. Therefore, most simulations included only the indicator contaminants as described.

The analysis also included an assessment of nonradiological cancer risk used in determining primary indicator contaminants for simulations in this EMCF and risk calculations in RPP-CALC-60498. Cancer risks from radionuclides and carcinogenic chemicals are typically reported as separate metrics rather than being summed because of differences in how risk is estimated for these two categories of substances. Of the nonradiological indicator contaminants, only chromium has a published cancer slope factor. For purposes of this analysis, chromium was assumed to be hexavalent chromium. The TC&WM EIS evaluated a longer list of nonradiological contaminants in the Best Basis Inventory (BBI) (DOE/ORP-2003-02) or in sample results and found chromium to be the only significant contributor to nonradiological ILCR within the A Barrier Boundary for the groundwater pathway. The degree to which the chromium ILCR provides an indication of total ILCR is uncertain because of the limited number of chemical analytes reported in the BBI. Hexavalent chromium toxicity values are applied to chromium concentration for this analysis. There is additional uncertainty regarding chromium speciation and the degree of conservatism introduced by assuming that all chromium is hexavalent chromium.

Peak human health impacts from all contaminants were estimated to occur in the following time ranges: 1) from before closure (calendar year 2050) to within 20 years after closure for past leaks and A-100-series tank retrieval leaks, 2) within 700 years after closure for AX-100-series tank retrieval leaks, and 3) within 1,800 years after closure for residual waste in tanks and ancillary equipment. The difference in peak concentration arrival times for retrieval leaks in the

A Farm versus the AX Farm is attributed to the hydraulic properties assigned in the TC&WM EIS AX farm model for a layer of fine sediments just above the water table (see Table N-1 in DOE/EIS-0391 Appendix N). Sediments at a similar depth within the A Farm model are coarser across most of the horizontal domain. Differences in peak concentrations and arrival times between tanks within the AX Farm are attributable to tank inventories, different distances upgradient from the fence line, and variability in the thickness and elevation of the layer of fine sediments from tank to tank.

The peak values in all cases were driven by contributions from the highly mobile (K_d = 0 mL/g) contaminants. Uranium and less mobile contaminants had not yet broken through to the water table at the time of peak breakthrough for any highly mobile contaminant source term and, therefore, made no contribution to the peak impacts. Tritium had decayed to insignificant levels at the time of peak impacts. Uranium exhibited increasing concentrations at the end of the 10,000 year simulation and was a primary contributor to the impacts at the end of the simulation. The impacts at the end of the simulation were lower than the peak impacts by an order of magnitude or more.

Tables 2 through 5 show the unit source simulation results for the indicator contaminants in the AX-101 through AX-104 retrieval leak source terms, respectively. The results indicated the peak groundwater concentrations from potential retrieval leaks at AX-100-series tanks would arrive at the WMA A/AX downgradient fence line between calendar years 2670 and 2745, depending on the locations of the sources. The time of peak concentrations from potential retrieval leaks was around calendar years 2701 to 2710 for AX-101, 2670 to 2696 for AX-102, 2739 to 2745 for AX-103, and 2672 to 2673 for AX-104. The values shown are the predicted peak contaminant concentrations in groundwater at the downgradient WMA A/AX fence line from release of 1 Ci of radionuclide or 1 kg of chemical. Three digits of precision are shown because the values are used in subsequent calculations of results with two digits of precision.

Table 2. Unit Inventory Simulation Results for AX-101 Retrieval Leak Source Term.

Contaminant	Time of Peak (Calendar Year)	Peak Groundwater Concentration per Unit Source	Units
Technetium-99	2706	1.32×10^{3}	pCi/L per Ci
Iodine-129	2710	1.31×10^{3}	pCi/L per Ci
Chromium	2710	1.31×10^{-3}	mg/L per kg
Nitrite	2701	1.33×10^{-3}	mg/L per kg
Nitrate	2703	1.32×10^{-3}	mg/L per kg

Tables 6 through 9 show the potential retrieval leak concentrations of the indicator contaminants based on results in RPP-RPT-58867, and the inventory associated with a hypothetical 4,000-gallon leak with those concentrations.

Table 3. Unit Inventory Simulation Results for AX-102 Retrieval Leak Source Term.

Contaminant	Time of Peak (Calendar Year)	Peak Groundwater Concentration per Unit Source	Units
Technetium-99	2671	6.76×10^{2}	pCi/L per Ci
Iodine-129	2672	6.79×10^{2}	pCi/L per Ci
Chromium	2672	6.79×10^{-4}	mg/L per kg
Nitrite	2696	6.74×10^{-4}	mg/L per kg
Nitrate	2670	6.75×10^{-4}	mg/L per kg

Table 4. Unit Inventory Simulation Results for AX-103 Retrieval Leak Source Term.

Contaminant	Time of Peak (Calendar Year)	Peak Groundwater Concentration per Unit Source	Units
Technetium-99	2743	5.84×10^{2}	pCi/L per Ci
Iodine-129	2745	5.87×10^{2}	pCi/L per Ci
Chromium	2745	5.87×10^{-4}	mg/L per kg
Nitrite	2739	5.84×10^{-4}	mg/L per kg
Nitrate	2741	5.85×10^{-4}	mg/L per kg

Tables 10 through 13 report the time and value of the peak groundwater concentration of each indicator contaminant in the AX-101 through AX-104 retrieval leak source terms, respectively. The groundwater concentrations are determined by multiplying the unit inventory results in Tables 2 through 5 by the corresponding inventory terms in Tables 6 through 9.

Table 14 reports the time and value of the peak groundwater concentration of each indicator contaminant in the A Farm retrieval leaks source term. The contaminant concentrations in the retrieval leaks from the AX Farm tanks were estimated by a different method than that used for the A Farm tanks.

The peak from A Farm retrieval leaks was estimated to arrive around calendar year 2068, and the peak from AX Farm retrieval leaks was estimated to arrive from calendar years 2670 to 2745. As noted, the difference is attributed primarily to the hydraulic properties of a layer of fine sediments occurring only below the AX tanks in the model. Ongoing evaluation of the

hydrogeology in WMA A/AX suggests that the layer may be both more widespread and have a higher hydraulic conductivity than that represented in the current model. If so, the peak concentrations from retrieval leaks in A Farm and AX Farm may arrive closer together in time, but still at different locations on the fence line.

Table 5. Unit Inventory Simulation Results for AX-104 Retrieval Leak Source Term.

Contaminant	Time of Peak (Calendar Year)	Peak Groundwater Concentration per Unit Source	Units
Technetium-99	2672	1.05×10^{3}	pCi/L per Ci
Iodine-129	2673	1.05×10^{3}	pCi/L per Ci
Chromium	2673	1.05×10^{-3}	mg/L per kg
Nitrite	2672	1.04×10^{-3}	mg/L per kg
Nitrate	2672	1.05×10^{-3}	mg/L per kg

The simulated peak concentrations from A Farm retrieval leaks overlap in time and are potentially additive with the simulated peak concentrations from past leaks, should the retrieval leaks occur in the time and manner assumed. The total impact of additive concentrations that could potentially occur as a result of multiple source release terms was not specifically evaluated here. Neither peak concentrations from A Farm retrieval leaks nor those from AX Farm retrieval leaks were simulated to be additive with peak concentrations from residual waste remaining in tanks and ancillary equipment. Declining concentrations from AX Farm retrieval leaks following the peak were simulated to overlap increasing concentrations from residual waste source terms prior to their peak, but at any given time between peaks, the impacts from one source term or the other are an order of magnitude lower than at the peak. If the fine sediment layer has higher hydraulic conductivities than modeled, the separation between peaks would likely be even greater, because even though all arrival times would be earlier, the breakthrough curves would be sharper.

Tables 15 and 16 report the time and value of the peak groundwater concentration of each indicator contaminant in the A Farm and AX Farm past releases source terms, respectively.

Table 17 reports the time and value of the peak groundwater concentration of each indicator contaminant from the A Farm and AX Farm past releases source terms by taking the maximum results from Tables 15 and 16.

Table 6. Tank AX-101 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration	Units	Inventory in 4,000-gal. Retrieval Leak	Units
Technetium-99	2.13×10^{-4}	Ci/L	3.23×10^{0}	Ci
Iodine-129	2.20×10^{-7}	Ci/L	3.34×10^{-3}	Ci
Chromium	4.51×10^{-3}	kg/L	6.83×10^{1}	kg
Nitrite (as NO_2)	1.21×10^{-1}	kg/L	1.83×10^{3}	kg
Nitrate (as NO_3)	2.47×10^{-1}	kg/L	3.74×10^{3}	kg
Uranium	1.22×10^{-3}	kg/L	1.85×10^{1}	kg

Source: RPP-RPT-58867, "AX Farm Groundwater Risk Constituent Concentration Determination."

Table 7. Tank AX-102 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration	Units	Inventory in 4,000-gal. Retrieval Leak	Units
Technetium-99	4.28×10^{-5}	Ci/L	6.48×10^{-1}	Ci
Iodine-129	1.16×10^{-7}	Ci/L	1.75×10^{-3}	Ci
Chromium	6.90×10^{-4}	kg/L	1.04×10^{1}	kg
Nitrite (as NO_2)	3.09×10^{-2}	kg/L	4.68×10^{2}	kg
Nitrate (as NO_3)	1.57×10^{-1}	kg/L	2.38×10^{3}	kg
Uranium	3.65×10^{-3}	kg/L	5.53×10^{1}	kg

Source: RPP-RPT-58867, "AX Farm Groundwater Risk Constituent Concentration Determination."

Table 8. Tank AX-103 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration	Units	Inventory in 4,000-gal. Retrieval Leak	Units
Technetium-99	1.60×10^{-4}	Ci/L	2.42×10^{0}	Ci
Iodine-129	1.57×10^{-7}	Ci/L	2.37×10^{-3}	Ci
Chromium	4.84×10^{-3}	kg/L	7.33×10^{1}	kg
Nitrite (as NO_2)	1.23×10^{-1}	kg/L	1.86×10^{3}	kg
Nitrate (as NO_3)	1.56×10^{-1}	kg/L	2.36×10^{3}	kg
Uranium	4.40×10^{-4}	kg/L	6.66×10^{0}	kg

Source: RPP-RPT-58867, "AX Farm Groundwater Risk Constituent Concentration Determination."

Table 9. Tank AX-104 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration	Units	Inventory in 4,000-gal. Retrieval Leak	Units
Technetium-99	3.14×10^{-4}	Ci/L	4.75×10^{0}	Ci
Iodine-129	5.67×10^{-9}	Ci/L	8.59×10^{-5}	Ci
Chromium	4.44×10^{-4}	kg/L	6.72×10^{0}	kg
Nitrite (as NO_2)	1.72×10^{-3}	kg/L	2.60×10^{1}	kg
Nitrate (as NO_3)	3.50×10^{-2}	kg/L	5.30×10^{2}	kg
Uranium	2.52×10^{-3}	kg/L	3.82×10^{1}	kg

Source: RPP-RPT-58867, "AX Farm Groundwater Risk Constituent Concentration Determination."

Table 10. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from a Potential Retrieval Leak at Tank AX-101.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2706	4,200	900	pCi/L
Iodine-129	2710	4.4	1	pCi/L
Chromium	2710	0.090	0.1[c]	mg/L
Nitrite (as NO_2)	2701	2.4[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2703	5.0[e]	45[e]	mg/L

Notes:

[a] Assumes one 4,000-gallon retrieval leak at composition from OLI Stream Analyzer.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

The results indicate the peak groundwater concentrations from past leaks would arrive at the WMA A/AX downgradient fence line around calendar years 2029 to 2054. The past leaks source terms were based on past unplanned releases modeled in the TC&WM EIS at tanks A-103, A-104, A-105, AX-102, and AX-104. Past releases at A-103, A-104, and A-105 were simulated separately from those at AX-102 and AX-104, and the maximum impacts between the simulations were reported since significant interaction between the two groups of releases is not predicted. That is, the overall maximum concentrations are attributable to larger, earlier releases from A-104 and A-105 that cause maximum concentrations at a point along the

southern portion of the fence line, whereas concentrations due to smaller, later releases from AX-102 and AX-104 peak around calendar year 2061 at a point on the eastern fence line.

Table 11. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from a Potential Retrieval Leak at Tank AX-102.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2671	440	900	pCi/L
Iodine-129	2672	1.2	1	pCi/L
Chromium	2672	0.0071	0.1[c]	mg/L
Nitrite (as NO_2)	2696	0.32[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2670	1.6[e]	45[e]	mg/L

Notes:
[a] Assumes one 4,000-gallon retrieval leak at composition from OLI Stream Analyzer.
[b] MCL = maximum contaminant level.
[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.
[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.
[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 12. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from a Potential Retrieval Leak at Tank AX-103

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2743	1,400	900	pCi/L
Iodine-129	2745	1.4	1	pCi/L
Chromium	2745	0.043	0.1[c]	mg/L
Nitrite (as NO_2)	2739	1.1[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2741	1.4[e]	45[e]	mg/L

Notes:
[a] Assumes one 4,000-gallon retrieval leak at composition from OLI Stream Analyzer.
[b] MCL = maximum contaminant level.
[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.
[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.
[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 13. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from a Potential Retrieval Leak at Tank AX-104.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2672	5,000	900	pCi/L
Iodine-129	2673	0.090	1	pCi/L
Chromium	2673	0.0071	0.1[c]	mg/L
Nitrite (as NO_2)	2672	0.027[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2672	0.55[e]	45[e]	mg/L

Notes:

[a] Assumes one 4,000-gallon retrieval leak at composition from OLI Stream Analyzer.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 14. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from Potential Retrieval Leaks at All A Farm Tanks.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2068	4,600	900	pCi/L
Iodine-129	2068	6.7	1	pCi/L
Chromium	2068	0.11	0.1[c]	mg/L
Nitrite (as NO_2)	2068	1.7[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2068	2.7[e]	45[e]	mg/L

Notes:

[a] Based on the maximum impacts of potential 4,000-gallon retrieval leaks from all six A-Farm 100-series tanks assuming all tanks leak simultaneously. Inventory used in TC&WM EIS.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 15. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from A Farm Past Releases.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2029	4,900	900	pCi/L
Iodine-129	2054	5.2	1	pCi/L
Chromium	2051	0.028	0.1[c]	mg/L
Nitrite (as NO_2)	2042	0.88[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2051	0.59[e]	45[e]	mg/L

Notes:

[a] Using past release source terms at A-103, A-104, and A-105 from TC&WM EIS except nitrite and nitrate calculated separately.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 16. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from AX Farm Past Releases.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2061	120	900	pCi/L
Iodine-129	2061	0.14	1	pCi/L
Chromium	2061	0.00081	0.1[c]	mg/L
Nitrite (as NO_2)	2061	0.015[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2061	0.029[e]	45[e]	mg/L

Notes:

[a] Using past release source terms at AX-102 and AX-104 from TC&WM EIS except nitrite and nitrate calculated separately.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 17. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from All Past Releases.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	2029	4,900	900	pCi/L
Iodine-129	2054	5.2	1	pCi/L
Chromium	2051	0.028	0.1[c]	mg/L
Nitrite (as NO_2)	2042	0.88[d]	3.3[d]	mg/L
Nitrate (as NO_3)	2051	0.59[e]	45[e]	mg/L

Notes:

[a] Maximum concentration for each contaminant from A Farm past leaks or AX Farm past leaks.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Groundwater concentrations were calculated as cumulative fence line maximum concentrations over the entire downgradient length of the WMA A/AX fence line. The peak groundwater concentrations from past leaks were simulated to overlap in time and thus be potentially additive with the peak groundwater concentrations from potential retrieval leaks from the A Farm tanks but were not simulated to be additive with the peaks from potential retrieval leaks from the AX Farm tanks or from residual waste remaining in tanks and ancillary equipment. The peak from A Farm retrieval leaks was estimated to arrive around calendar year 2068 compared with 2029 to 2054 for the past leaks.

Transport of contaminants from past releases was based on water flow from the original releases and natural recharge only (i.e., surface infiltration of meteoric water). The effect on existing contamination of artificial recharge, such as a retrieval leak or water line leak, was not explicitly simulated. Generally speaking, should the fluid released in a retrieval leak intercept an existing vadose zone plume in WMA A/AX, there is a potential for the contamination to be flushed more quickly to the water table. The effect of the flushing on peak groundwater concentration and arrival time would depend on a number of factors, including initial plume depth and the rate, volume, and location of the retrieval leak. If this were to occur, the WMA A/AX past leak impacts could differ from the projected impacts shown in Table 17, which were calculated assuming meteoric infiltration. However, until the assumed time of final closure in calendar year 2050, an enhanced average rate of infiltration is assumed based on disturbance of soil and vegetation (DOE/EIS-0391). It is assumed that near the SSTs the enhanced meteoric infiltration at a rate of 100 mm/yr exceeds artificial recharge such as the estimated raw water loss levels in RPP-ENV-37956, pp. 5-4.

Tables 18 and 19 report the time and value of the peak groundwater concentration of each indicator contaminant in the A Farm and AX Farm tank residuals source terms, respectively.

Table 18. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from A Farm Tank Residuals.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	3384	4,400	900	pCi/L
Iodine-129	3705	3.6	1	pCi/L
Chromium	3327	0.11	0.1[c]	mg/L
Nitrite (as NO_2)	3327	3.1[d]	3.3[d]	mg/L
Nitrate (as NO_3)	3327	5.0[e]	45[e]	mg/L

Notes:
[a] Using potential tank residuals source release term from TC&WM EIS except nitrite and nitrate calculated separately.
[b] MCL = maximum contaminant level.
[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.
[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.
[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 19. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from AX Farm Tank Residuals.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	3236	3,400	900	pCi/L
Iodine-129	3559	2.8	1	pCi/L
Chromium	3166	0.063	0.1[c]	mg/L
Nitrite (as NO_2)	3159	1.9[d]	3.3[d]	mg/L
Nitrate (as NO_3)	3161	3.6[e]	45[e]	mg/L

Notes:
[a] Using potential tank residuals source release term from TC&WM EIS except nitrite and nitrate calculated separately.
[b] MCL = maximum contaminant level.
[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.
[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.
[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 20 reports the time and value of the peak groundwater concentration of each indicator contaminant from the A Farm and AX Farm tank residuals source terms by taking the maximum results from Tables 18 and 19.

Table 20. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from All Tank Residuals.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	3384	4,400	900	pCi/L
Iodine-129	3705	3.6	1	pCi/L
Chromium	3327	0.11	0.1[c]	mg/L
Nitrite (as NO_2)	3327	3.1[d]	3.3[d]	mg/L
Nitrate (as NO_3)	3327	5.0[e]	45[e]	mg/L

Notes:
[a] Maximum concentration for each contaminant from A Farm tank residuals or AX Farm tank residuals.
[b] MCL = maximum contaminant level.
[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.
[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.
[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

The results indicate the peak groundwater concentrations from residual tank waste would arrive at the fence line approximately from calendar years 3327 to 3705. The different grouted waste K_d values for the indicator contaminants are responsible for the separation in peak arrival times of the different contaminants. If a diffusion-limited release model were additionally assumed for the contaminant releases from the tank residuals, resulting peak concentrations would be expected to be lower and occur later in time, because a diffusion-limited release would result in a lower release rate.

The peak groundwater concentrations from residual tank waste were simulated to overlap in time and thus be potentially additive with the peak groundwater concentrations from residual ancillary equipment waste but were not simulated to be additive with the peaks from past leaks or potential retrieval leaks.

Tables 21 and 22 report the time and value of the peak groundwater concentration of each indicator contaminant in the A Farm and AX Farm ancillary equipment residuals source terms, respectively.

Table 23 reports the time and value of the peak groundwater concentration of each indicator contaminant from the A Farm and AX Farm ancillary equipment residuals source terms by taking the maximum results from Tables 21 and 22.

The results indicate the peak groundwater concentrations from residual ancillary equipment waste would arrive at the fence line approximately from calendar years 3357 to 3708. The different grouted waste K_d values for the indicator contaminants are responsible for the separation in peak arrival times of the different contaminants. If a diffusion-limited release

model were additionally assumed for the contaminant releases from residuals for some of the ancillary equipment that will be grouted, resulting peak concentrations would be expected to be lower and occur later in time, because a diffusion-limited release would result in a lower release rate. Results reported for the WMA-wide maximum impacts also blend impacts from differing ancillary equipment residual inventories transported along different subsurface pathways such that impacts to the eastern fence line from the AX Farm and impacts to the southern fence line from the A Farm by different contaminants are reported together and are assumed to be additive for a given metric.

Table 21. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from A Farm Ancillary Equipment Residuals.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	3506	2,100	900	pCi/L
Iodine-129	3708	2.3	1	pCi/L
Chromium	3476	0.050	0.1[c]	mg/L
Nitrite (as NO_2)	3475	1.5[d]	3.3[d]	mg/L
Nitrate (as NO_3)	3475	2.3[e]	45[e]	mg/L

Notes:

[a] Using potential ancillary equipment residuals source release term from TC&WM EIS except nitrite and nitrate calculated separately.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

The peak groundwater concentrations from residual ancillary equipment waste were simulated to overlap in time and thus be potentially additive with the peak groundwater concentrations from residual tank waste but were not simulated to be additive with the peaks from past leaks or potential retrieval leaks.

Peak groundwater calculations determined in this EMCF provide the basis for calculation of peak ILCR and HI for groundwater exposure scenarios considered in RPP-CALC-60498.

Table 22. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from AX Farm Ancillary Equipment Residuals.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	3391	2,300	900	pCi/L
Iodine-129	3615	2.1	1	pCi/L
Chromium	3361	0.043	0.1[c]	mg/L
Nitrite (as NO_2)	3355	1.3[d]	3.3[d]	mg/L
Nitrate (as NO_3)	3357	2.4[e]	45[e]	mg/L

Notes:

[a] Using potential ancillary equipment residuals source release term from TC&WM EIS except nitrite and nitrate calculated separately.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

Table 23. Peak Groundwater Concentration at the Waste Management Area A/AX Fence Line from All Ancillary Equipment Residuals.

Contaminant	Time of Peak (Calendar Year)	Groundwater Concentration[a]	Drinking Water Standard (MCL)[b]	Units
Technetium-99	3391	2,300	900	pCi/L
Iodine-129	3708	2.3	1	pCi/L
Chromium	3476	0.050	0.1[c]	mg/L
Nitrite (as NO_2)	3475	1.5[d]	3.3[d]	mg/L
Nitrate (as NO_3)	3357	2.4[e]	45[e]	mg/L

Notes:

[a] Maximum concentration for each contaminant from A Farm ancillary equipment residuals or AX Farm ancillary equipment residuals.

[b] MCL = maximum contaminant level.

[c] MCL for total chromium. No MCL for hexavalent chromium has been published by U.S. Environmental Protection Agency.

[d] Concentration and MCL for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

[e] Concentration and MCL for nitrate reported as the ion. The MCL for nitrate reported as nitrogen is 10 mg/L.

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ATTACHMENT 1

CALCULATION OF SATURATED ZONE CONDITIONS FROM CENTRAL PLATEAU GROUNDWATER MODEL

Workbook File	Attachment_1_RPP-CALC_60497.xlsx
Workbook Creator	Arun Wahi (INTERA, Inc.) HID#H0396269
Date Originally Created	9/22/2015
Workbook Purpose	This spreadsheet documents two sets of calculations used to establish saturated zone conditions for the WMA A/AX TWRWP models in RPP-CALC-60497.

SPREADSHEET NAME	DESCRIPTION	CREATED BY	LAST DATE UPDATED
Workbook Notes	Summary-level notes related to this workbook	Arun Wahi (INTERA)	9/22/2015
Elevation_Head_CPGWM_window	contains raw output for hydraulic head predictions from the CPGWM calibration Version 3.3 for selected model cells, as well as model layer elevations.	Arun Wahi (INTERA)	9/22/2015
CPGWM_gradient_and_satd_thick	Selected data were copied to CPGWM_gradient_and_satd_thick for calculations of the average saturated thickness and the hydraulic gradient	Arun Wahi (INTERA)	9/22/2015
AFarm_indices_and_BCs*	Tabulates the A Farm i and j indices in a matrix to calculate coordinates. parameters for boundary condition calculations are at the top in the far righthand corner. West, north, and east boundary conditions are calculated at the far right. South boundary conditions are calculated at the bottom and transposed below the list at the far right.	Arun Wahi (INTERA)	9/22/2015
AXFarm_indices_and_BCs*	tabulates the AX Farm i and j indices in a matrix to calculate coordinates. Parameters for boundary condition calculations are at the top in the far righthand corner. West, north, and east boundary conditions are calculated at the far right. South boundary conditions are calculated at the bottom and transposed below the list at the far right.	Arun Wahi (INTERA)	9/22/2015

* Some further text editing of the results is necessary to apply line breaks and other syntax before using with STOMP.

row	column	TopElv_L1	TopElv_L2	TopElv_L3	TopElv_L4	TopElv_L5	TopElv_L6	TopElv_L7	BotElv_L7	head_2014	head_2100
70	195	128.00	122.00	117.50	112.90	108.40	103.80	102.80	101.80	121.52	119.4968
70	196	128.20	122.00	117.30	112.40	107.50	102.50	101.50	100.50	121.52	119.4964
70	197	128.50	122.00	118.50	113.30	108.10	102.90	101.90	100.90	121.52	119.4956
70	198	128.80	121.70	117.60	113.40	109.30	105.20	103.70	102.20	121.52	119.4934
70	199	129.10	126.40	122.00	117.00	112.00	107.00	104.70	102.40	121.51	119.4888
70	200	129.40	128.00	122.00	117.50	113.00	108.40	105.40	102.40	121.51	119.4847
70	201	130.50	129.50	122.00	117.80	113.60	109.50	105.90	102.30	121.50	119.4796
71	195	127.80	122.00	117.10	112.10	107.20	105.60	102.60	99.69	121.52	119.4963
71	196	128.00	122.00	117.80	113.70	109.20	104.60	102.10	99.57	121.52	119.4959
71	197	128.30	122.00	117.00	113.00	109.00	105.00	102.20	99.45	121.52	119.4949
71	198	128.50	125.40	122.00	116.90	111.70	106.60	103.10	99.58	121.52	119.4923
71	199	128.80	125.80	122.00	117.40	112.80	108.20	103.90	99.59	121.50	119.4840
71	200	129.10	123.60	122.00	117.80	113.50	109.30	104.40	99.61	121.50	119.4821
71	201	129.40	127.10	122.00	118.00	114.00	110.00	104.80	99.59	121.50	119.4785
72	195	127.60	122.00	118.50	115.00	111.50	107.10	101.70	96.22	121.52	119.4958
72	196	127.80	122.00	118.60	114.70	110.70	106.80	101.80	96.70	121.52	119.4956
72	197	128.10	124.90	122.00	117.10	112.30	107.40	102.10	96.89	121.52	119.4938
72	198	128.30	124.80	122.00	117.60	113.20	108.70	102.90	96.99	121.50	119.4847
72	199	128.50	122.00	118.50	115.00	111.50	110.00	103.80	97.58	121.50	119.4829
72	200	128.80	122.00	118.80	115.60	112.40	110.50	103.70	97.00	121.50	119.4819
72	201	129.10	122.00	119.00	116.30	113.50	110.80	103.70	96.67	121.50	119.4806
73	195	127.50	122.00	119.10	116.10	113.20	108.70	100.80	92.88	121.52	119.4949
73	196	127.60	122.00	120.10	116.30	112.50	108.70	100.90	93.05	121.52	119.4942
73	197	127.80	126.30	122.10	117.80	113.60	109.30	101.20	93.15	121.51	119.4918
73	198	128.00	123.60	122.10	118.20	114.40	110.60	102.00	93.39	121.51	119.4866
73	199	128.20	122.00	119.50	116.90	114.30	111.70	102.90	94.08	121.50	119.4827
73	200	128.50	122.00	119.00	116.00	113.10	111.50	102.50	93.54	121.50	119.4816
73	201	128.70	122.00	120.00	117.10	114.30	111.50	102.30	93.07	121.50	119.4808
74	195	127.20	122.00	119.00	116.10	113.10	110.00	99.89	89.73	121.52	119.4938
74	196	127.40	122.00	119.30	116.50	113.30	110.10	99.90	89.68	121.52	119.4929
74	197	127.50	122.10	119.80	117.60	114.10	110.60	100.10	89.63	121.51	119.4918
74	198	127.70	124.50	122.10	118.50	115.00	111.40	100.50	89.61	121.51	119.4901
74	199	127.90	122.70	120.00	117.40	114.70	112.00	100.80	89.66	121.50	119.4826
74	200	128.10	122.00	120.30	118.60	115.40	112.10	100.90	89.73	121.50	119.4813
74	201	128.30	124.90	122.00	118.70	115.40	112.10	101.00	89.87	121.50	119.4776

row	column	TopElv_L1	TopElv_L2	TopElv_L3	TopElv_L4	TopElv_L5	TopElv_L6	TopElv_L7	BotElv_L7	head_2014	head_2100
70	196	128.20	122.00	117.30	112.40	107.50	102.50	101.50	100.50	121.5218	119.4964
70	197	128.50	122.00	118.50	113.30	108.10	102.90	101.90	100.90	121.5207	119.4956
70	198	128.80	121.70	117.60	113.40	109.30	105.20	103.70	102.20	121.5189	119.4934
70	199	129.10	126.40	122.00	117.00	112.00	107.00	104.70	102.40	121.5118	119.4888
70	200	129.40	128.00	122.00	117.50	113.00	108.40	105.40	102.40	121.5065	119.4847
71	196	128.00	122.00	117.80	113.70	109.20	104.60	102.10	99.57	121.5210	119.4959
71	197	128.30	122.00	117.00	113.00	109.00	105.00	102.20	99.45	121.5199	119.4949
71	198	128.50	125.40	122.00	116.90	111.70	106.60	103.10	99.58	121.5166	119.4923
71	199	128.80	125.80	122.00	117.40	112.80	108.20	103.90	99.59	121.5034	119.4840
71	200	129.10	123.60	122.00	117.80	113.50	109.30	104.40	99.61	121.5007	119.4821
72	196	127.80	122.00	118.60	114.70	110.70	106.80	101.80	96.70	121.5201	119.4956
72	197	128.10	124.90	122.00	117.10	112.30	107.40	102.10	96.89	121.5185	119.4938
72	198	128.30	124.80	122.00	117.60	113.20	108.70	102.90	96.99	121.5042	119.4847
72	199	128.50	122.00	118.50	115.00	111.50	110.00	103.80	97.58	121.5015	119.4829
72	200	128.80	122.00	118.80	115.60	112.40	110.50	103.70	97.00	121.5002	119.4819
73	196	127.60	122.00	120.10	116.30	112.50	108.70	100.90	93.05	121.5179	119.4942
73	197	127.80	126.30	122.10	117.80	113.60	109.30	101.20	93.15	121.5145	119.4918
73	198	128.00	123.60	122.10	118.20	114.40	110.60	102.00	93.39	121.5060	119.4866
73	199	128.20	122.00	119.50	116.90	114.30	111.70	102.90	94.08	121.5011	119.4827
73	200	128.50	122.00	119.00	116.00	113.10	111.50	102.50	93.54	121.4999	119.4816
74	196	127.40	122.00	119.30	116.50	113.30	110.10	99.90	89.68	121.5155	119.4929
74	197	127.50	122.10	119.80	117.60	114.10	110.60	100.10	89.63	121.5136	119.4918
74	198	127.70	124.50	122.10	118.50	115.00	111.40	100.50	89.61	121.5117	119.4901
74	199	127.90	122.70	120.00	117.40	114.70	112.00	100.80	89.66	121.5015	119.4826
74	200	128.10	122.00	120.30	118.60	115.40	112.10	100.90	89.73	121.4997	119.4813

	NW - SW	NE - SE	
dh	0.0035	0.0034	
dy	400	400	
dh/dy	8.7E-06	8.5E-06	
	NE - NW	SE - SW	
dh	-0.0117	-0.0116	
dx	400	400	
dh/dx	-2.92E-05	-2.90E-05	
			average
dh/dl	3.05E-05	3.02E-05	3.04E-05
angle	-2.91E-01	-2.85E-01	-2.88E-01
angle (degrees N of E)	-1.67E+01	-1.63E+01	-1.65E+01

row	column	b_L1	b_L2	b_L3	b_L4	b_L5	b_L6	b_L7	b	b_2-5
70	196	0	2.1964	4.9	4.9	5	1	1	18.9964	16.9964
70	197	0	0.9956	5.2	5.2	5.2	1	1	18.5956	16.5956
70	198	0	1.8934	4.2	4.1	4.1	1.5	1.5	17.2934	14.2934
70	199	0	0	2.4888	5	5	2.3	2.3	17.0888	12.4888
70	200	0	0	1.9847	4.5	4.6	3	3	17.0847	11.0847
71	196	0	1.6959	4.1	4.5	4.6	2.5	2.53	19.9259	14.8959
71	197	0	2.4949	4	4	4	2.8	2.75	20.0449	14.4949
71	198	0	0	2.5923	5.2	5.1	3.5	3.52	19.9123	12.8923
71	199	0	0	2.084	4.6	4.6	4.3	4.31	19.894	11.284
71	200	0	0	1.6821	4.3	4.2	4.9	4.79	19.8721	10.1821
72	196	0	0.8956	3.9	4	3.9	5	5.1	22.7956	12.6956
72	197	0	0	2.3938	4.8	4.9	5.3	5.21	22.6038	12.0938
72	198	0	0	1.8847	4.4	4.5	5.8	5.91	22.4947	10.7847
72	199	0	0.9829	3.5	3.5	1.5	6.2	6.22	21.9029	9.4829
72	200	0	0.6819	3.2	3.2	1.9	6.8	6.7	22.4819	8.9819
73	196	0	0	3.1942	3.8	3.8	7.8	7.85	26.4442	10.7942
73	197	0	0	1.6918	4.2	4.3	8.1	8.05	26.3418	10.1918
73	198	0	0	1.2866	3.8	3.8	8.6	8.61	26.0966	8.8866
73	199	0	0	2.5827	2.6	2.6	8.8	8.82	25.4027	7.7827
73	200	0	0.4816	3	2.9	1.6	9	8.96	25.9416	7.9816
74	196	0	0.1929	2.8	3.2	3.2	10.2	10.22	29.8129	9.3929
74	197	0	0	1.8918	3.5	3.5	10.5	10.47	29.8618	8.8918
74	198	0	0	0.9901	3.5	3.6	10.9	10.89	29.8801	8.0901
74	199	0	0	2.0826	2.7	2.7	11.2	11.14	29.8226	7.4826
74	200	0	0	0.8813	3.2	3.3	11.2	11.17	29.7513	7.3813

average b	all layers	to bottom of layer 5
	23.2	11.0

row	column	ThicknessL1	ThicknessL2	ThicknessL3	ThicknessL4	ThicknessL5	ThicknessL6	ThicknessL7
70	196	6.20	4.70	4.90	4.90	5.00	1.00	1.00
70	197	6.50	3.50	5.20	5.20	5.20	1.00	1.00

70	198	7.10	4.10	4.20	4.10	4.10	1.50	1.50
70	199	2.70	4.40	5.00	5.00	5.00	2.30	2.30
70	200	1.40	6.00	4.50	4.50	4.60	3.00	3.00
71	196	6.00	4.20	4.10	4.50	4.60	2.50	2.53
71	197	6.30	5.00	4.00	4.00	4.00	2.80	2.75
71	198	3.10	3.40	5.10	5.20	5.10	3.50	3.52
71	199	3.00	3.80	4.60	4.60	4.60	4.30	4.31
71	200	5.50	1.60	4.20	4.30	4.20	4.90	4.79
72	196	5.80	3.40	3.90	4.00	3.90	5.00	5.10
72	197	3.20	2.90	4.90	4.80	4.90	5.30	5.21
72	198	3.50	2.80	4.40	4.40	4.50	5.80	5.91
72	199	6.50	3.50	3.50	3.50	1.50	6.20	6.22
72	200	6.80	3.20	3.20	3.20	1.90	6.80	6.70
73	196	5.60	1.90	3.80	3.80	3.80	7.80	7.85
73	197	1.50	4.20	4.30	4.20	4.30	8.10	8.05
73	198	4.40	1.50	3.90	3.80	3.80	8.60	8.61
73	199	6.20	2.50	2.60	2.60	2.60	8.80	8.82
73	200	6.50	3.00	3.00	2.90	1.60	9.00	8.96
74	196	5.40	2.70	2.80	3.20	3.20	10.20	10.22
74	197	5.40	2.30	2.20	3.50	3.50	10.50	10.47
74	198	3.20	2.40	3.60	3.50	3.60	10.90	10.89
74	199	5.20	2.70	2.60	2.70	2.70	11.20	11.14
74	200	6.10	1.70	1.70	3.20	3.30	11.20	11.17

~Grid Card
Cartesian

48	42	~~45~~	53										
0 m	1@38	m	1@25	m	1@16	m	1@11	m	1@7	m	15@5	m	
0 m	1@38	m	1@25	m	1@16	m	1@11	m	1@7	m	15@5	m	
~~0 m~~	~~45@2~~	~~m~~											
0 m	11@1	m	42@2	m									

575160 135881 SW Corner A Domain
575353 136058.5 Centroid A Domain

Node Coordinates			i spacing	West Edge	1@38	1@25	1@16	1@11	1@7	15@5	15@5	15@5	15@5	
			i spacing	West Edge		38	25	16	11	7	5	5	5	5
			Easting (m)		575160	575179	575210.5	575231	575244.5	575253.5	575259.5	575264.5	575269.5	575274.5
j spacing	j spacing	Northing (m)	j ^ / i >	West Edge		1	2	3	4	5	6	7	8	9
North Edge	North Edge	136236	North Edge	West Edge,North Ed	1,North Edge	2,North Edge	3,North Edge	4,North Edge	5,North Edge	6,North Edge	7,North Edge	8,North Edge	9,North Edge	
1@38	38	136217	42	West Edge,42	1,42	2,42	3,42	4,42	5,42	6,42	7,42	8,42	9,42	
1@25	25	136185.5	41	West Edge,41	1,41	2,41	3,41	4,41	5,41	6,41	7,41	8,41	9,41	
1@16	16	136165	40	West Edge,40	1,40	2,40	3,40	4,40	5,40	6,40	7,40	8,40	9,40	
1@11	11	136151.5	39	West Edge,39	1,39	2,39	3,39	4,39	5,39	6,39	7,39	8,39	9,39	
1@7	7	136142.5	38	West Edge,38	1,38	2,38	3,38	4,38	5,38	6,38	7,38	8,38	9,38	
15@5	5	136136.5	37	West Edge,37	1,37	2,37	3,37	4,37	5,37	6,37	7,37	8,37	9,37	
15@5	5	136131.5	36	West Edge,36	1,36	2,36	3,36	4,36	5,36	6,36	7,36	8,36	9,36	
15@5	5	136126.5	35	West Edge,35	1,35	2,35	3,35	4,35	5,35	6,35	7,35	8,35	9,35	
15@5	5	136121.5	34	West Edge,34	1,34	2,34	3,34	4,34	5,34	6,34	7,34	8,34	9,34	
15@5	5	136116.5	33	West Edge,33	1,33	2,33	3,33	4,33	5,33	6,33	7,33	8,33	9,33	
15@5	5	136111.5	32	West Edge,32	1,32	2,32	3,32	4,32	5,32	6,32	7,32	8,32	9,32	
15@5	5	136106.5	31	West Edge,31	1,31	2,31	3,31	4,31	5,31	6,31	7,31	8,31	9,31	
15@5	5	136101.5	30	West Edge,30	1,30	2,30	3,30	4,30	5,30	6,30	7,30	8,30	9,30	
15@5	5	136096.5	29	West Edge,29	1,29	2,29	3,29	4,29	5,29	6,29	7,29	8,29	9,29	
15@5	5	136091.5	28	West Edge,28	1,28	2,28	3,28	4,28	5,28	6,28	7,28	8,28	9,28	
15@5	5	136086.5	27	West Edge,27	1,27	2,27	3,27	4,27	5,27	6,27	7,27	8,27	9,27	
15@5	5	136081.5	26	West Edge,26	1,26	2,26	3,26	4,26	5,26	6,26	7,26	8,26	9,26	
15@5	5	136076.5	25	West Edge,25	1,25	2,25	3,25	4,25	5,25	6,25	7,25	8,25	9,25	
15@5	5	136071.5	24	West Edge,24	1,24	2,24	3,24	4,24	5,24	6,24	7,24	8,24	9,24	
15@5	5	136066.5	23	West Edge,23	1,23	2,23	3,23	4,23	5,23	6,23	7,23	8,23	9,23	
2@5.5	5.5	136061.25	22	West Edge,22	1,22	2,22	3,22	4,22	5,22	6,22	7,22	8,22	9,22	
2@5.5	5.5	136055.75	21	West Edge,21	1,21	2,21	3,21	4,21	5,21	6,21	7,21	8,21	9,21	
15@5	5	136050.5	20	West Edge,20	1,20	2,20	3,20	4,20	5,20	6,20	7,20	8,20	9,20	
15@5	5	136045.5	19	West Edge,19	1,19	2,19	3,19	4,19	5,19	6,19	7,19	8,19	9,19	
15@5	5	136040.5	18	West Edge,18	1,18	2,18	3,18	4,18	5,18	6,18	7,18	8,18	9,18	
15@5	5	136035.5	17	West Edge,17	1,17	2,17	3,17	4,17	5,17	6,17	7,17	8,17	9,17	
15@5	5	136030.5	16	West Edge,16	1,16	2,16	3,16	4,16	5,16	6,16	7,16	8,16	9,16	
15@5	5	136025.5	15	West Edge,15	1,15	2,15	3,15	4,15	5,15	6,15	7,15	8,15	9,15	
15@5	5	136020.5	14	West Edge,14	1,14	2,14	3,14	4,14	5,14	6,14	7,14	8,14	9,14	
15@5	5	136015.5	13	West Edge,13	1,13	2,13	3,13	4,13	5,13	6,13	7,13	8,13	9,13	
15@5	5	136010.5	12	West Edge,12	1,12	2,12	3,12	4,12	5,12	6,12	7,12	8,12	9,12	
15@5	5	136005.5	11	West Edge,11	1,11	2,11	3,11	4,11	5,11	6,11	7,11	8,11	9,11	
15@5	5	136000.5	10	West Edge,10	1,10	2,10	3,10	4,10	5,10	6,10	7,10	8,10	9,10	
15@5	5	135995.5	9	West Edge,9	1,9	2,9	3,9	4,9	5,9	6,9	7,9	8,9	9,9	
15@5	5	135990.5	8	West Edge,8	1,8	2,8	3,8	4,8	5,8	6,8	7,8	8,8	9,8	
15@5	5	135985.5	7	West Edge,7	1,7	2,7	3,7	4,7	5,7	6,7	7,7	8,7	9,7	
15@5	5	135980.5	6	West Edge,6	1,6	2,6	3,6	4,6	5,6	6,6	7,6	8,6	9,6	

1@7	7	135974.5	5	West Edge,5	1,5		2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5		
1@11	11	135965.5	4	West Edge,4	1,4		2,4	3,4	4,4	5,4	6,4	7,4	8,4	9,4		
1@16	16	135952	3	West Edge,3	1,3		2,3	3,3	4,3	5,3	6,3	7,3	8,3	9,3		
1@25	25	135931.5	2	West Edge,2	1,2		2,2	3,2	4,2	5,2	6,2	7,2	8,2	9,2		
1@38	38	135900	1	West Edge,1	1,1		2,1	3,1	4,1	5,1	6,1	7,1	8,1	9,1		
South Edge	South Edge	135881	South Edge	West Edge,South Ed	1,South Edge		2,South Edge	3,South Edge	4,South Edge	5,South Edge	6,South Edge	7,South Edge	8,South Edge	9,South Edge		
Boundary C	Boundary C	Boundary Cor	Boundary Cond	Boundary Condition		119.502461	119.502238	119.502093	119.501998	119.501934	119.501892	119.501856	119.501821	119.501785		
BC k=1 Pre	BC k=1 Pre	BC k=1 Pressu	BC k=1 Pressure	BC k=1 Pressure (Pa)		204181.05	204178.87	204177.45	204176.51	204175.89	204175.48	204175.13	204174.78	204174.44		

South,Hydraulic Gradient,Outflow,1,1,1,: South,Hydraulic Gradi South,Hydraulic Gra South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi

2@5.5	m	4@5	m	2@5.5	m	15@5	m	1@7	m	1@11	m
2@5.5	m	15@5	m	1@7	m	1@11	m	1@16	m	1@25	m

15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	2@5.5
5	5	5	5	5	5	5	5	5	5	5	5.5
575279.5	575284.5	575289.5	575294.5	575299.5	575304.5	575309.5	575314.5	575319.5	575324.5	575329.5	575334.75
10	11	12	13	14	15	16	17	18	19	20	21
10,North Edge	11,North Edge	12,North Edge	13,North Edge	14,North Edge	15,North Edge	16,North Edge	17,North Edge	18,North Edge	19,North Edge	20,North Edge	21,North Edge
10,42	11,42	12,42	13,42	14,42	15,42	16,42	17,42	18,42	19,42	20,42	21,42
10,41	11,41	12,41	13,41	14,41	15,41	16,41	17,41	18,41	19,41	20,41	21,41
10,40	11,40	12,40	13,40	14,40	15,40	16,40	17,40	18,40	19,40	20,40	21,40
10,39	11,39	12,39	13,39	14,39	15,39	16,39	17,39	18,39	19,39	20,39	21,39
10,38	11,38	12,38	13,38	14,38	15,38	16,38	17,38	18,38	19,38	20,38	21,38
10,37	11,37	12,37	13,37	14,37	15,37	16,37	17,37	18,37	19,37	20,37	21,37
10,36	11,36	12,36	13,36	14,36	15,36	16,36	17,36	18,36	19,36	20,36	21,36
10,35	11,35	12,35	13,35	14,35	15,35	16,35	17,35	18,35	19,35	20,35	21,35
10,34	11,34	12,34	13,34	14,34	15,34	16,34	17,34	18,34	19,34	20,34	21,34
10,33	11,33	12,33	13,33	14,33	15,33	16,33	17,33	18,33	19,33	20,33	21,33
10,32	11,32	12,32	13,32	14,32	15,32	16,32	17,32	18,32	19,32	20,32	21,32
10,31	11,31	12,31	13,31	14,31	15,31	16,31	17,31	18,31	19,31	20,31	21,31
10,30	11,30	12,30	13,30	14,30	15,30	16,30	17,30	18,30	19,30	20,30	21,30
10,29	11,29	12,29	13,29	14,29	15,29	16,29	17,29	18,29	19,29	20,29	21,29
10,28	11,28	12,28	13,28	14,28	15,28	16,28	17,28	18,28	19,28	20,28	21,28
10,27	11,27	12,27	13,27	14,27	15,27	16,27	17,27	18,27	19,27	20,27	21,27
10,26	11,26	12,26	13,26	14,26	15,26	16,26	17,26	18,26	19,26	20,26	21,26
10,25	11,25	12,25	13,25	14,25	15,25	16,25	17,25	18,25	19,25	20,25	21,25
10,24	11,24	12,24	13,24	14,24	15,24	16,24	17,24	18,24	19,24	20,24	21,24
10,23	11,23	12,23	13,23	14,23	15,23	16,23	17,23	18,23	19,23	20,23	21,23
10,22	11,22	12,22	13,22	14,22	15,22	16,22	17,22	18,22	19,22	20,22	21,22
10,21	11,21	12,21	13,21	14,21	15,21	16,21	17,21	18,21	19,21	20,21	21,21
10,20	11,20	12,20	13,20	14,20	15,20	16,20	17,20	18,20	19,20	20,20	21,20
10,19	11,19	12,19	13,19	14,19	15,19	16,19	17,19	18,19	19,19	20,19	21,19
10,18	11,18	12,18	13,18	14,18	15,18	16,18	17,18	18,18	19,18	20,18	21,18
10,17	11,17	12,17	13,17	14,17	15,17	16,17	17,17	18,17	19,17	20,17	21,17
10,16	11,16	12,16	13,16	14,16	15,16	16,16	17,16	18,16	19,16	20,16	21,16
10,15	11,15	12,15	13,15	14,15	15,15	16,15	17,15	18,15	19,15	20,15	21,15
10,14	11,14	12,14	13,14	14,14	15,14	16,14	17,14	18,14	19,14	20,14	21,14
10,13	11,13	12,13	13,13	14,13	15,13	16,13	17,13	18,13	19,13	20,13	21,13
10,12	11,12	12,12	13,12	14,12	15,12	16,12	17,12	18,12	19,12	20,12	21,12
10,11	11,11	12,11	13,11	14,11	15,11	16,11	17,11	18,11	19,11	20,11	21,11
10,10	11,10	12,10	13,10	14,10	15,10	16,10	17,10	18,10	19,10	20,10	21,10
10,9	11,9	12,9	13,9	14,9	15,9	16,9	17,9	18,9	19,9	20,9	21,9
10,8	11,8	12,8	13,8	14,8	15,8	16,8	17,8	18,8	19,8	20,8	21,8
10,7	11,7	12,7	13,7	14,7	15,7	16,7	17,7	18,7	19,7	20,7	21,7
10,6	11,6	12,6	13,6	14,6	15,6	16,6	17,6	18,6	19,6	20,6	21,6

10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5	19,5	20,5	21,5
10,4	11,4	12,4	13,4	14,4	15,4	16,4	17,4	18,4	19,4	20,4	21,4
10,3	11,3	12,3	13,3	14,3	15,3	16,3	17,3	18,3	19,3	20,3	21,3
10,2	11,2	12,2	13,2	14,2	15,2	16,2	17,2	18,2	19,2	20,2	21,2
10,1	11,1	12,1	13,1	14,1	15,1	16,1	17,1	18,1	19,1	20,1	21,1
10,South Edge	11,South Edge	12,South Edge	13,South Edge	14,South Edge	15,South Edge	16,South Edge	17,South Edge	18,South Edge	19,South Edge	20,South Edge	21,South Edge
119.501750	119.501715	119.501679	119.501644	119.501609	119.501573	119.501538	119.501503	119.501467	119.501432	119.501397	119.501359
204174.09	204173.74	204173.40	204173.05	204172.71	204172.36	204172.01	204171.67	204171.32	204170.97	204170.63	204170.27
South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradie

1@16	m	1@25	m	1@38	m
1@38	m				

2@5.5	4@5	4@5	4@5	4@5	2@5.5	2@5.5	15@5	15@5	15@5	15@5	15@5
5.5	5	5	5	5	5.5	5.5	5	5	5	5	5
575340.25	575345.5	575350.5	575355.5	575360.5	575365.75	575371.25	575376.5	575381.5	575386.5	575391.5	575396.5
22	23	24	25	26	27	28	29	30	31	32	33
22,North Edge	23,North Edge	24,North Edge	25,North Edge	26,North Edge	27,North Edge	28,North Edge	29,North Edge	30,North Edge	31,North Edge	32,North Edge	33,North Edge
22,42	23,42	24,42	25,42	26,42	27,42	28,42	29,42	30,42	31,42	32,42	33,42
22,41	23,41	24,41	25,41	26,41	27,41	28,41	29,41	30,41	31,41	32,41	33,41
22,40	23,40	24,40	25,40	26,40	27,40	28,40	29,40	30,40	31,40	32,40	33,40
22,39	23,39	24,39	25,39	26,39	27,39	28,39	29,39	30,39	31,39	32,39	33,39
22,38	23,38	24,38	25,38	26,38	27,38	28,38	29,38	30,38	31,38	32,38	33,38
22,37	23,37	24,37	25,37	26,37	27,37	28,37	29,37	30,37	31,37	32,37	33,37
22,36	23,36	24,36	25,36	26,36	27,36	28,36	29,36	30,36	31,36	32,36	33,36
22,35	23,35	24,35	25,35	26,35	27,35	28,35	29,35	30,35	31,35	32,35	33,35
22,34	23,34	24,34	25,34	26,34	27,34	28,34	29,34	30,34	31,34	32,34	33,34
22,33	23,33	24,33	25,33	26,33	27,33	28,33	29,33	30,33	31,33	32,33	33,33
22,32	23,32	24,32	25,32	26,32	27,32	28,32	29,32	30,32	31,32	32,32	33,32
22,31	23,31	24,31	25,31	26,31	27,31	28,31	29,31	30,31	31,31	32,31	33,31
22,30	23,30	24,30	25,30	26,30	27,30	28,30	29,30	30,30	31,30	32,30	33,30
22,29	23,29	24,29	25,29	26,29	27,29	28,29	29,29	30,29	31,29	32,29	33,29
22,28	23,28	24,28	25,28	26,28	27,28	28,28	29,28	30,28	31,28	32,28	33,28
22,27	23,27	24,27	25,27	26,27	27,27	28,27	29,27	30,27	31,27	32,27	33,27
22,26	23,26	24,26	25,26	26,26	27,26	28,26	29,26	30,26	31,26	32,26	33,26
22,25	23,25	24,25	25,25	26,25	27,25	28,25	29,25	30,25	31,25	32,25	33,25
22,24	23,24	24,24	25,24	26,24	27,24	28,24	29,24	30,24	31,24	32,24	33,24
22,23	23,23	24,23	25,23	26,23	27,23	28,23	29,23	30,23	31,23	32,23	33,23
22,22	23,22	24,22	25,22	26,22	27,22	28,22	29,22	30,22	31,22	32,22	33,22
22,21	23,21	24,21	25,21	26,21	27,21	28,21	29,21	30,21	31,21	32,21	33,21
22,20	23,20	24,20	25,20	26,20	27,20	28,20	29,20	30,20	31,20	32,20	33,20
22,19	23,19	24,19	25,19	26,19	27,19	28,19	29,19	30,19	31,19	32,19	33,19
22,18	23,18	24,18	25,18	26,18	27,18	28,18	29,18	30,18	31,18	32,18	33,18
22,17	23,17	24,17	25,17	26,17	27,17	28,17	29,17	30,17	31,17	32,17	33,17
22,16	23,16	24,16	25,16	26,16	27,16	28,16	29,16	30,16	31,16	32,16	33,16
22,15	23,15	24,15	25,15	26,15	27,15	28,15	29,15	30,15	31,15	32,15	33,15
22,14	23,14	24,14	25,14	26,14	27,14	28,14	29,14	30,14	31,14	32,14	33,14
22,13	23,13	24,13	25,13	26,13	27,13	28,13	29,13	30,13	31,13	32,13	33,13
22,12	23,12	24,12	25,12	26,12	27,12	28,12	29,12	30,12	31,12	32,12	33,12
22,11	23,11	24,11	25,11	26,11	27,11	28,11	29,11	30,11	31,11	32,11	33,11
22,10	23,10	24,10	25,10	26,10	27,10	28,10	29,10	30,10	31,10	32,10	33,10
22,9	23,9	24,9	25,9	26,9	27,9	28,9	29,9	30,9	31,9	32,9	33,9
22,8	23,8	24,8	25,8	26,8	27,8	28,8	29,8	30,8	31,8	32,8	33,8
22,7	23,7	24,7	25,7	26,7	27,7	28,7	29,7	30,7	31,7	32,7	33,7
22,6	23,6	24,6	25,6	26,6	27,6	28,6	29,6	30,6	31,6	32,6	33,6

22,5	23,5	24,5	25,5	26,5	27,5	28,5	29,5	30,5	31,5	32,5	33,5
22,4	23,4	24,4	25,4	26,4	27,4	28,4	29,4	30,4	31,4	32,4	33,4
22,3	23,3	24,3	25,3	26,3	27,3	28,3	29,3	30,3	31,3	32,3	33,3
22,2	23,2	24,2	25,2	26,2	27,2	28,2	29,2	30,2	31,2	32,2	33,2
22,1	23,1	24,1	25,1	26,1	27,1	28,1	29,1	30,1	31,1	32,1	33,1
22,South Edge	23,South Edge	24,South Edge	25,South Edge	26,South Edge	27,South Edge	28,South Edge	29,South Edge	30,South Edge	31,South Edge	32,South Edge	33,South Edge
119.501321	119.501283	119.501248	119.501213	119.501177	119.501140	119.501101	119.501064	119.501029	119.500993	119.500958	119.500923
204169.88	204169.52	204169.17	204168.83	204168.48	204168.12	204167.74	204167.37	204167.03	204166.68	204166.34	204165.99

South,Hydraulic Gradie	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradie	South,Hydraulic Gradie	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi

Aquifer defined to be 11 m below arbitrary
with uniform K, with water table at top of k
A Farm model boundary conditions specifie

dP/dh from STOMP User's Guide-->
implied local g consistent with metro Seattl
Not used:

NIST webbook rho @ 2	998.207
standard g	9.80665

15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	1@7	1@11	1@16
5	5	5	5	5	5	5	5	5	5	7	11	16
575401.5	575406.5	575411.5	575416.5	575421.5	575426.5	575431.5	575436.5	575441.5	575446.5	575452.5	575461.5	575475
34	35	36	37	38	39	40	41	42	43	44	45	46
34,North Edge	35,North Edge	36,North Edge	37,North Edge	38,North Edge	39,North Edge	40,North Edge	41,North Edge	42,North Edge	43,North Edge	44,North Edge	45,North Edge	46,North Edge
34,42	35,42	36,42	37,42	38,42	39,42	40,42	41,42	42,42	43,42	44,42	45,42	46,42
34,41	35,41	36,41	37,41	38,41	39,41	40,41	41,41	42,41	43,41	44,41	45,41	46,41
34,40	35,40	36,40	37,40	38,40	39,40	40,40	41,40	42,40	43,40	44,40	45,40	46,40
34,39	35,39	36,39	37,39	38,39	39,39	40,39	41,39	42,39	43,39	44,39	45,39	46,39
34,38	35,38	36,38	37,38	38,38	39,38	40,38	41,38	42,38	43,38	44,38	45,38	46,38
34,37	35,37	36,37	37,37	38,37	39,37	40,37	41,37	42,37	43,37	44,37	45,37	46,37
34,36	35,36	36,36	37,36	38,36	39,36	40,36	41,36	42,36	43,36	44,36	45,36	46,36
34,35	35,35	36,35	37,35	38,35	39,35	40,35	41,35	42,35	43,35	44,35	45,35	46,35
34,34	35,34	36,34	37,34	38,34	39,34	40,34	41,34	42,34	43,34	44,34	45,34	46,34
34,33	35,33	36,33	37,33	38,33	39,33	40,33	41,33	42,33	43,33	44,33	45,33	46,33
34,32	35,32	36,32	37,32	38,32	39,32	40,32	41,32	42,32	43,32	44,32	45,32	46,32
34,31	35,31	36,31	37,31	38,31	39,31	40,31	41,31	42,31	43,31	44,31	45,31	46,31
34,30	35,30	36,30	37,30	38,30	39,30	40,30	41,30	42,30	43,30	44,30	45,30	46,30
34,29	35,29	36,29	37,29	38,29	39,29	40,29	41,29	42,29	43,29	44,29	45,29	46,29
34,28	35,28	36,28	37,28	38,28	39,28	40,28	41,28	42,28	43,28	44,28	45,28	46,28
34,27	35,27	36,27	37,27	38,27	39,27	40,27	41,27	42,27	43,27	44,27	45,27	46,27
34,26	35,26	36,26	37,26	38,26	39,26	40,26	41,26	42,26	43,26	44,26	45,26	46,26
34,25	35,25	36,25	37,25	38,25	39,25	40,25	41,25	42,25	43,25	44,25	45,25	46,25
34,24	35,24	36,24	37,24	38,24	39,24	40,24	41,24	42,24	43,24	44,24	45,24	46,24
34,23	35,23	36,23	37,23	38,23	39,23	40,23	41,23	42,23	43,23	44,23	45,23	46,23
34,22	35,22	36,22	37,22	38,22	39,22	40,22	41,22	42,22	43,22	44,22	45,22	46,22
34,21	35,21	36,21	37,21	38,21	39,21	40,21	41,21	42,21	43,21	44,21	45,21	46,21
34,20	35,20	36,20	37,20	38,20	39,20	40,20	41,20	42,20	43,20	44,20	45,20	46,20
34,19	35,19	36,19	37,19	38,19	39,19	40,19	41,19	42,19	43,19	44,19	45,19	46,19
34,18	35,18	36,18	37,18	38,18	39,18	40,18	41,18	42,18	43,18	44,18	45,18	46,18
34,17	35,17	36,17	37,17	38,17	39,17	40,17	41,17	42,17	43,17	44,17	45,17	46,17
34,16	35,16	36,16	37,16	38,16	39,16	40,16	41,16	42,16	43,16	44,16	45,16	46,16
34,15	35,15	36,15	37,15	38,15	39,15	40,15	41,15	42,15	43,15	44,15	45,15	46,15
34,14	35,14	36,14	37,14	38,14	39,14	40,14	41,14	42,14	43,14	44,14	45,14	46,14
34,13	35,13	36,13	37,13	38,13	39,13	40,13	41,13	42,13	43,13	44,13	45,13	46,13
34,12	35,12	36,12	37,12	38,12	39,12	40,12	41,12	42,12	43,12	44,12	45,12	46,12
34,11	35,11	36,11	37,11	38,11	39,11	40,11	41,11	42,11	43,11	44,11	45,11	46,11
34,10	35,10	36,10	37,10	38,10	39,10	40,10	41,10	42,10	43,10	44,10	45,10	46,10
34,9	35,9	36,9	37,9	38,9	39,9	40,9	41,9	42,9	43,9	44,9	45,9	46,9
34,8	35,8	36,8	37,8	38,8	39,8	40,8	41,8	42,8	43,8	44,8	45,8	46,8
34,7	35,7	36,7	37,7	38,7	39,7	40,7	41,7	42,7	43,7	44,7	45,7	46,7
34,6	35,6	36,6	37,6	38,6	39,6	40,6	41,6	42,6	43,6	44,6	45,6	46,6

34,5	35,5	36,5	37,5	38,5	39,5	40,5	41,5	42,5	43,5	44,5	45,5	46,5
34,4	35,4	36,4	37,4	38,4	39,4	40,4	41,4	42,4	43,4	44,4	45,4	46,4
34,3	35,3	36,3	37,3	38,3	39,3	40,3	41,3	42,3	43,3	44,3	45,3	46,3
34,2	35,2	36,2	37,2	38,2	39,2	40,2	41,2	42,2	43,2	44,2	45,2	46,2
34,1	35,1	36,1	37,1	38,1	39,1	40,1	41,1	42,1	43,1	44,1	45,1	46,1
34,South Edge	35,South Edge	36,South Edge	37,South Edge	38,South Edge	39,South Edge	40,South Edge	41,South Edge	42,South Edge	43,South Edge	44,South Edge	45,South Edge	46,South Edge
119.500887	119.500852	119.500817	119.500781	119.500746	119.500711	119.500675	119.500640	119.500605	119.500569	119.500527	119.500463	119.500368
204165.64	204165.30	204164.95	204164.60	204164.26	204163.91	204163.57	204163.22	204162.87	204162.53	204162.11	204161.49	204160.55

South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gradi	South,Hydraulic Gra

SS WLE		SE node WLE (m)	119.5			
:=11.		gradient	1.00E-05		K (m/d)	1750
ed independent of AX Farm		direction	S of E		d/yr	365.2425
		degrees	45			
		gradient_i	-7.07107E-06		q_i (m/yr)	4.51965
		gradient_j	7.07107E-06		q_j (m/yr)	-4.51965
		dP/dh (Pa/m) = rho*	-9793.5192			
le		Patm (Pa)	101325			
kg/m3		base elev (m)	108.5			
m/s2		k=1 node elev (m)	109.0			
1@25	1@38	East Edge	BC WLE (m)	BC k=1 Pressure (Pa)		**Boundary Conditions:**
25	38	East Edge	BC WLE (m)	BC k=1 Pressure (Pa)		West,Neumann,Outflow,1,1,1,42,1,11,1,0,yr,4.51965,m/yr,,,
575495.5	575527	575546	BC WLE (m)	BC k=1 Pressure (Pa)		North,Neumann,Outflow,1,48,42,42,1,11,1,0,yr,-4.51965,m/yr,,,
47	48	East Edge	BC WLE (m)	BC k=1 Pressure (Pa)		
47,North Edge	48,North Edge	East Edge,North Edg	BC WLE (m)	BC k=1 Pressure (Pa)		
47,42	48,42	East Edge,42	119.502242	204178.90		East,Hydraulic Gradient,Outflow,48,48,42,42,1,11,1,0,yr,204178.9,Pa,,,
47,41	48,41	East Edge,41	119.502019	204176.72		East,Hydraulic Gradient,Outflow,48,48,41,41,1,11,1,0,yr,204176.72,Pa,,,
47,40	48,40	East Edge,40	119.501874	204175.30		East,Hydraulic Gradient,Outflow,48,48,40,40,1,11,1,0,yr,204175.3,Pa,,,
47,39	48,39	East Edge,39	119.501778	204174.37		East,Hydraulic Gradient,Outflow,48,48,39,39,1,11,1,0,yr,204174.37,Pa,,,
47,38	48,38	East Edge,38	119.501715	204173.74		East,Hydraulic Gradient,Outflow,48,48,38,38,1,11,1,0,yr,204173.74,Pa,,,
47,37	48,37	East Edge,37	119.501672	204173.33		East,Hydraulic Gradient,Outflow,48,48,37,37,1,11,1,0,yr,204173.33,Pa,,,
47,36	48,36	East Edge,36	119.501637	204172.98		East,Hydraulic Gradient,Outflow,48,48,36,36,1,11,1,0,yr,204172.98,Pa,,,
47,35	48,35	East Edge,35	119.501602	204172.64		East,Hydraulic Gradient,Outflow,48,48,35,35,1,11,1,0,yr,204172.64,Pa,,,
47,34	48,34	East Edge,34	119.501566	204172.29		East,Hydraulic Gradient,Outflow,48,48,34,34,1,11,1,0,yr,204172.29,Pa,,,
47,33	48,33	East Edge,33	119.501531	204171.94		East,Hydraulic Gradient,Outflow,48,48,33,33,1,11,1,0,yr,204171.94,Pa,,,
47,32	48,32	East Edge,32	119.501496	204171.60		East,Hydraulic Gradient,Outflow,48,48,32,32,1,11,1,0,yr,204171.6,Pa,,,
47,31	48,31	East Edge,31	119.501460	204171.25		East,Hydraulic Gradient,Outflow,48,48,31,31,1,11,1,0,yr,204171.25,Pa,,,
47,30	48,30	East Edge,30	119.501425	204170.91		East,Hydraulic Gradient,Outflow,48,48,30,30,1,11,1,0,yr,204170.91,Pa,,,
47,29	48,29	East Edge,29	119.501389	204170.56		East,Hydraulic Gradient,Outflow,48,48,29,29,1,11,1,0,yr,204170.56,Pa,,,
47,28	48,28	East Edge,28	119.501354	204170.21		East,Hydraulic Gradient,Outflow,48,48,28,28,1,11,1,0,yr,204170.21,Pa,,,
47,27	48,27	East Edge,27	119.501319	204169.87		East,Hydraulic Gradient,Outflow,48,48,27,27,1,11,1,0,yr,204169.87,Pa,,,
47,26	48,26	East Edge,26	119.501283	204169.52		East,Hydraulic Gradient,Outflow,48,48,26,26,1,11,1,0,yr,204169.52,Pa,,,
47,25	48,25	East Edge,25	119.501248	204169.17		East,Hydraulic Gradient,Outflow,48,48,25,25,1,11,1,0,yr,204169.17,Pa,,,
47,24	48,24	East Edge,24	119.501213	204168.83		East,Hydraulic Gradient,Outflow,48,48,24,24,1,11,1,0,yr,204168.83,Pa,,,
47,23	48,23	East Edge,23	119.501177	204168.48		East,Hydraulic Gradient,Outflow,48,48,23,23,1,11,1,0,yr,204168.48,Pa,,,
47,22	48,22	East Edge,22	119.501140	204168.12		East,Hydraulic Gradient,Outflow,48,48,22,22,1,11,1,0,yr,204168.12,Pa,,,
47,21	48,21	East Edge,21	119.501101	204167.74		East,Hydraulic Gradient,Outflow,48,48,21,21,1,11,1,0,yr,204167.74,Pa,,,
47,20	48,20	East Edge,20	119.501064	204167.37		East,Hydraulic Gradient,Outflow,48,48,20,20,1,11,1,0,yr,204167.37,Pa,,,
47,19	48,19	East Edge,19	119.501029	204167.03		East,Hydraulic Gradient,Outflow,48,48,19,19,1,11,1,0,yr,204167.03,Pa,,,
47,18	48,18	East Edge,18	119.500993	204166.68		East,Hydraulic Gradient,Outflow,48,48,18,18,1,11,1,0,yr,204166.68,Pa,,,
47,17	48,17	East Edge,17	119.500958	204166.34		East,Hydraulic Gradient,Outflow,48,48,17,17,1,11,1,0,yr,204166.34,Pa,,,
47,16	48,16	East Edge,16	119.500923	204165.99		East,Hydraulic Gradient,Outflow,48,48,16,16,1,11,1,0,yr,204165.99,Pa,,,
47,15	48,15	East Edge,15	119.500887	204165.64		East,Hydraulic Gradient,Outflow,48,48,15,15,1,11,1,0,yr,204165.64,Pa,,,
47,14	48,14	East Edge,14	119.500852	204165.30		East,Hydraulic Gradient,Outflow,48,48,14,14,1,11,1,0,yr,204165.3,Pa,,,
47,13	48,13	East Edge,13	119.500817	204164.95		East,Hydraulic Gradient,Outflow,48,48,13,13,1,11,1,0,yr,204164.95,Pa,,,
47,12	48,12	East Edge,12	119.500781	204164.60		East,Hydraulic Gradient,Outflow,48,48,12,12,1,11,1,0,yr,204164.6,Pa,,,
47,11	48,11	East Edge,11	119.500746	204164.26		East,Hydraulic Gradient,Outflow,48,48,11,11,1,11,1,0,yr,204164.26,Pa,,,
47,10	48,10	East Edge,10	119.500711	204163.91		East,Hydraulic Gradient,Outflow,48,48,10,10,1,11,1,0,yr,204163.91,Pa,,,
47,9	48,9	East Edge,9	119.500675	204163.57		East,Hydraulic Gradient,Outflow,48,48,9,9,1,11,1,0,yr,204163.57,Pa,,,
47,8	48,8	East Edge,8	119.500640	204163.22		East,Hydraulic Gradient,Outflow,48,48,8,8,1,11,1,0,yr,204163.22,Pa,,,
47,7	48,7	East Edge,7	119.500605	204162.87		East,Hydraulic Gradient,Outflow,48,48,7,7,1,11,1,0,yr,204162.87,Pa,,,
47,6	48,6	East Edge,6	119.500569	204162.53		East,Hydraulic Gradient,Outflow,48,48,6,6,1,11,1,0,yr,204162.53,Pa,,,

47,5	48,5	East Edge,5	119.500527	204162.11	East,Hydraulic Gradient,Outflow,48,48,5,5,1,11,1,0,yr,204162.11,Pa,,,
47,4	48,4	East Edge,4	119.500463	204161.49	East,Hydraulic Gradient,Outflow,48,48,4,4,1,11,1,0,yr,204161.49,Pa,,,
47,3	48,3	East Edge,3	119.500368	204160.55	East,Hydraulic Gradient,Outflow,48,48,3,3,1,11,1,0,yr,204160.55,Pa,,,
47,2	48,2	East Edge,2	119.500223	204159.13	East,Hydraulic Gradient,Outflow,48,48,2,2,1,11,1,0,yr,204159.13,Pa,,,
47,1	48,1	East Edge,1	119.500000	204156.95	East,Hydraulic Gradient,Outflow,48,48,1,1,1,11,1,0,yr,204156.95,Pa,,,
47,South Edge	48,South Edge	East Edge,South Edge			
119.500223	119.500000				
204159.13	204156.95				

South,Hydraulic Gradi South,Hydraulic Gradient,Outflow,48,48,1,1,1,11,1,0,yr,204156.95,Pa,,,

South,Hydraulic Gradient,Outflow,1,1,1,1,1,11,1,0,yr,204181.05,Pa,,,
South,Hydraulic Gradient,Outflow,2,2,1,1,1,11,1,0,yr,204178.87,Pa,,,
South,Hydraulic Gradient,Outflow,3,3,1,1,1,11,1,0,yr,204177.45,Pa,,,
South,Hydraulic Gradient,Outflow,4,4,1,1,1,11,1,0,yr,204176.51,Pa,,,
South,Hydraulic Gradient,Outflow,5,5,1,1,1,11,1,0,yr,204175.89,Pa,,,
South,Hydraulic Gradient,Outflow,6,6,1,1,1,11,1,0,yr,204175.48,Pa,,,
South,Hydraulic Gradient,Outflow,7,7,1,1,1,11,1,0,yr,204175.13,Pa,,,
South,Hydraulic Gradient,Outflow,8,8,1,1,1,11,1,0,yr,204174.78,Pa,,,
South,Hydraulic Gradient,Outflow,9,9,1,1,1,11,1,0,yr,204174.44,Pa,,,
South,Hydraulic Gradient,Outflow,10,10,1,1,1,11,1,0,yr,204174.09,Pa,,,
South,Hydraulic Gradient,Outflow,11,11,1,1,1,11,1,0,yr,204173.74,Pa,,,
South,Hydraulic Gradient,Outflow,12,12,1,1,1,11,1,0,yr,204173.4,Pa,,,
South,Hydraulic Gradient,Outflow,13,13,1,1,1,11,1,0,yr,204173.05,Pa,,,
South,Hydraulic Gradient,Outflow,14,14,1,1,1,11,1,0,yr,204172.71,Pa,,,
South,Hydraulic Gradient,Outflow,15,15,1,1,1,11,1,0,yr,204172.36,Pa,,,
South,Hydraulic Gradient,Outflow,16,16,1,1,1,11,1,0,yr,204172.01,Pa,,,
South,Hydraulic Gradient,Outflow,17,17,1,1,1,11,1,0,yr,204171.67,Pa,,,
South,Hydraulic Gradient,Outflow,18,18,1,1,1,11,1,0,yr,204171.32,Pa,,,
South,Hydraulic Gradient,Outflow,19,19,1,1,1,11,1,0,yr,204170.97,Pa,,,
South,Hydraulic Gradient,Outflow,20,20,1,1,1,11,1,0,yr,204170.63,Pa,,,
South,Hydraulic Gradient,Outflow,21,21,1,1,1,11,1,0,yr,204170.27,Pa,,,
South,Hydraulic Gradient,Outflow,22,22,1,1,1,11,1,0,yr,204169.88,Pa,,,
South,Hydraulic Gradient,Outflow,23,23,1,1,1,11,1,0,yr,204169.52,Pa,,,
South,Hydraulic Gradient,Outflow,24,24,1,1,1,11,1,0,yr,204169.17,Pa,,,
South,Hydraulic Gradient,Outflow,25,25,1,1,1,11,1,0,yr,204168.83,Pa,,,
South,Hydraulic Gradient,Outflow,26,26,1,1,1,11,1,0,yr,204168.48,Pa,,,
South,Hydraulic Gradient,Outflow,27,27,1,1,1,11,1,0,yr,204168.12,Pa,,,
South,Hydraulic Gradient,Outflow,28,28,1,1,1,11,1,0,yr,204167.74,Pa,,,
South,Hydraulic Gradient,Outflow,29,29,1,1,1,11,1,0,yr,204167.37,Pa,,,
South,Hydraulic Gradient,Outflow,30,30,1,1,1,11,1,0,yr,204167.03,Pa,,,
South,Hydraulic Gradient,Outflow,31,31,1,1,1,11,1,0,yr,204166.68,Pa,,,
South,Hydraulic Gradient,Outflow,32,32,1,1,1,11,1,0,yr,204166.34,Pa,,,
South,Hydraulic Gradient,Outflow,33,33,1,1,1,11,1,0,yr,204165.99,Pa,,,
South,Hydraulic Gradient,Outflow,34,34,1,1,1,11,1,0,yr,204165.64,Pa,,,
South,Hydraulic Gradient,Outflow,35,35,1,1,1,11,1,0,yr,204165.3,Pa,,,
South,Hydraulic Gradient,Outflow,36,36,1,1,1,11,1,0,yr,204164.95,Pa,,,
South,Hydraulic Gradient,Outflow,37,37,1,1,1,11,1,0,yr,204164.6,Pa,,,
South,Hydraulic Gradient,Outflow,38,38,1,1,1,11,1,0,yr,204164.26,Pa,,,
South,Hydraulic Gradient,Outflow,39,39,1,1,1,11,1,0,yr,204163.91,Pa,,,
South,Hydraulic Gradient,Outflow,40,40,1,1,1,11,1,0,yr,204163.57,Pa,,,
South,Hydraulic Gradient,Outflow,41,41,1,1,1,11,1,0,yr,204163.22,Pa,,,
South,Hydraulic Gradient,Outflow,42,42,1,1,1,11,1,0,yr,204162.87,Pa,,,
South,Hydraulic Gradient,Outflow,43,43,1,1,1,11,1,0,yr,204162.53,Pa,,,
South,Hydraulic Gradient,Outflow,44,44,1,1,1,11,1,0,yr,204162.11,Pa,,,
South,Hydraulic Gradient,Outflow,45,45,1,1,1,11,1,0,yr,204161.49,Pa,,,
South,Hydraulic Gradient,Outflow,46,46,1,1,1,11,1,0,yr,204160.55,Pa,,,
South,Hydraulic Gradient,Outflow,47,47,1,1,1,11,1,0,yr,204159.13,Pa,,,
South,Hydraulic Gradient,Outflow,48,48,1,1,1,11,1,0,yr,204156.95,Pa,,,

select destination range, define transpose, CTRL+SHIFT+ENTER

~Grid Card
Cartesian

42	42	~~41~~	52										
0 m	1@38	m	1@25	m	1@16	m	1@11	m	1@7	m	15@5	m	
0 m	1@38	m	1@25	m	1@16	m	1@11	m	1@7	m	15@5	m	
~~0 m~~	~~41@2~~	~~m~~											
0 m	11@1	m	41@2	m									

575232 136011 SW Corner AX Domain
575408 136188.5 Centroid AX Domain
background recharge
enhanced recharge

Node Coordinates			i spacing	West Edge	1@38	1@25	1@16	1@11	1@7	15@5	15@5	15@5	15@5
			i spacing	West Edge	38	25	16	11	7	5	5	5	5
			Easting (m)		575232	575251	575282.5	575303	575316.5	575325.5	575331.5	575336.5	575341.5	575346.5
j spacing	j spacing	Northing (m)	j ^ / i >	West Edge	1	2	3	4	5	6	7	8	9
North Edge	North Edge	136366	North Edge	West Edge,North Ed	1,North Edge	2,North Edge	3,North Edge	4,North Edge	5,North Edge	6,North Edge	7,North Edge	8,North Edge	9,North Edge
1@38	38	136347	42	West Edge,42	1,42	2,42	3,42	4,42	5,42	6,42	7,42	8,42	9,42
1@25	25	136315.5	41	West Edge,41	1,41	2,41	3,41	4,41	5,41	6,41	7,41	8,41	9,41
1@16	16	136295	40	West Edge,40	1,40	2,40	3,40	4,40	5,40	6,40	7,40	8,40	9,40
1@11	11	136281.5	39	West Edge,39	1,39	2,39	3,39	4,39	5,39	6,39	7,39	8,39	9,39
1@7	7	136272.5	38	West Edge,38	1,38	2,38	3,38	4,38	5,38	6,38	7,38	8,38	9,38
15@5	5	136266.5	37	West Edge,37	1,37	2,37	3,37	4,37	5,37	6,37	7,37	8,37	9,37
15@5	5	136261.5	36	West Edge,36	1,36	2,36	3,36	4,36	5,36	6,36	7,36	8,36	9,36
15@5	5	136256.5	35	West Edge,35	1,35	2,35	3,35	4,35	5,35	6,35	7,35	8,35	9,35
15@5	5	136251.5	34	West Edge,34	1,34	2,34	3,34	4,34	5,34	6,34	7,34	8,34	9,34
15@5	5	136246.5	33	West Edge,33	1,33	2,33	3,33	4,33	5,33	6,33	7,33	8,33	9,33
15@5	5	136241.5	32	West Edge,32	1,32	2,32	3,32	4,32	5,32	6,32	7,32	8,32	9,32
15@5	5	136236.5	31	West Edge,31	1,31	2,31	3,31	4,31	5,31	6,31	7,31	8,31	9,31
15@5	5	136231.5	30	West Edge,30	1,30	2,30	3,30	4,30	5,30	6,30	7,30	8,30	9,30
15@5	5	136226.5	29	West Edge,29	1,29	2,29	3,29	4,29	5,29	6,29	7,29	8,29	9,29
15@5	5	136221.5	28	West Edge,28	1,28	2,28	3,28	4,28	5,28	6,28	7,28	8,28	9,28
15@5	5	136216.5	27	West Edge,27	1,27	2,27	3,27	4,27	5,27	6,27	7,27	8,27	9,27
15@5	5	136211.5	26	West Edge,26	1,26	2,26	3,26	4,26	5,26	6,26	7,26	8,26	9,26
15@5	5	136206.5	25	West Edge,25	1,25	2,25	3,25	4,25	5,25	6,25	7,25	8,25	9,25
15@5	5	136201.5	24	West Edge,24	1,24	2,24	3,24	4,24	5,24	6,24	7,24	8,24	9,24
15@5	5	136196.5	23	West Edge,23	1,23	2,23	3,23	4,23	5,23	6,23	7,23	8,23	9,23
2@5.5	5.5	136191.25	22	West Edge,22	1,22	2,22	3,22	4,22	5,22	6,22	7,22	8,22	9,22
2@5.5	5.5	136185.75	21	West Edge,21	1,21	2,21	3,21	4,21	5,21	6,21	7,21	8,21	9,21
15@5	5	136180.5	20	West Edge,20	1,20	2,20	3,20	4,20	5,20	6,20	7,20	8,20	9,20
15@5	5	136175.5	19	West Edge,19	1,19	2,19	3,19	4,19	5,19	6,19	7,19	8,19	9,19
15@5	5	136170.5	18	West Edge,18	1,18	2,18	3,18	4,18	5,18	6,18	7,18	8,18	9,18
15@5	5	136165.5	17	West Edge,17	1,17	2,17	3,17	4,17	5,17	6,17	7,17	8,17	9,17
15@5	5	136160.5	16	West Edge,16	1,16	2,16	3,16	4,16	5,16	6,16	7,16	8,16	9,16
15@5	5	136155.5	15	West Edge,15	1,15	2,15	3,15	4,15	5,15	6,15	7,15	8,15	9,15
15@5	5	136150.5	14	West Edge,14	1,14	2,14	3,14	4,14	5,14	6,14	7,14	8,14	9,14
15@5	5	136145.5	13	West Edge,13	1,13	2,13	3,13	4,13	5,13	6,13	7,13	8,13	9,13
15@5	5	136140.5	12	West Edge,12	1,12	2,12	3,12	4,12	5,12	6,12	7,12	8,12	9,12
15@5	5	136135.5	11	West Edge,11	1,11	2,11	3,11	4,11	5,11	6,11	7,11	8,11	9,11

15@5	5	136130.5	10	West Edge,10	1,10	2,10	3,10	4,10	5,10	6,10	7,10	8,10	9,10	
15@5	5	136125.5	9	West Edge,9	1,9	2,9	3,9	4,9	5,9	6,9	7,9	8,9	9,9	
15@5	5	136120.5	8	West Edge,8	1,8	2,8	3,8	4,8	5,8	6,8	7,8	8,8	9,8	
15@5	5	136115.5	7	West Edge,7	1,7	2,7	3,7	4,7	5,7	6,7	7,7	8,7	9,7	
15@5	5	136110.5	6	West Edge,6	1,6	2,6	3,6	4,6	5,6	6,6	7,6	8,6	9,6	
1@7	7	136104.5	5	West Edge,5	1,5	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	
1@11	11	136095.5	4	West Edge,4	1,4	2,4	3,4	4,4	5,4	6,4	7,4	8,4	9,4	
1@16	16	136082	3	West Edge,3	1,3	2,3	3,3	4,3	5,3	6,3	7,3	8,3	9,3	
1@25	25	136061.5	2	West Edge,2	1,2	2,2	3,2	4,2	5,2	6,2	7,2	8,2	9,2	
1@38	38	136030	1	West Edge,1	1,1	2,1	3,1	4,1	5,1	6,1	7,1	8,1	9,1	
South Edge	South Edge	136011	South Edge	West Edge,South Ed	1,South Edge	2,South Edge	3,South Edge	4,South Edge	5,South Edge	6,South Edge	7,South Edge	8,South Edge	9,South Edge	
Boundary (	Boundary (	Boundary Cor	Boundary Condition WLE		119.502220	119.501998	119.501853	119.501757	119.501694	119.501651	119.501616	119.501580	119.501545	
BC k=1 Pre	BC k=1 Pre	BC k=1 Pressu	BC k=1 Pressure (Pa)		204178.70	204176.51	204175.10	204174.16	204173.54	204173.12	204172.78	204172.43	204172.08	

South,Hydraulic Gra South,Hydraulic Gradi South,Hydraulic Gra South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi

2@4	m	15@5	m	1@7	m	1@11	m	1@16	m	1@25	m
2@5.5	m	15@5	m	1@7	m	1@11	m	1@16	m	1@25	m

15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	2@4
5	5	5	5	5	5	5	5	5	5	5	5	4
575351.5	575356.5	575361.5	575366.5	575371.5	575376.5	575381.5	575386.5	575391.5	575396.5	575401.5	575406	
10	11	12	13	14	15	16	17	18	19	20	21	
10,North Edge	11,North Edge	12,North Edge	13,North Edge	14,North Edge	15,North Edge	16,North Edge	17,North Edge	18,North Edge	19,North Edge	20,North Edge	21,North Edge	
10,42	11,42	12,42	13,42	14,42	15,42	16,42	17,42	18,42	19,42	20,42	21,42	
10,41	11,41	12,41	13,41	14,41	15,41	16,41	17,41	18,41	19,41	20,41	21,41	
10,40	11,40	12,40	13,40	14,40	15,40	16,40	17,40	18,40	19,40	20,40	21,40	
10,39	11,39	12,39	13,39	14,39	15,39	16,39	17,39	18,39	19,39	20,39	21,39	
10,38	11,38	12,38	13,38	14,38	15,38	16,38	17,38	18,38	19,38	20,38	21,38	
10,37	11,37	12,37	13,37	14,37	15,37	16,37	17,37	18,37	19,37	20,37	21,37	
10,36	11,36	12,36	13,36	14,36	15,36	16,36	17,36	18,36	19,36	20,36	21,36	
10,35	11,35	12,35	13,35	14,35	15,35	16,35	17,35	18,35	19,35	20,35	21,35	
10,34	11,34	12,34	13,34	14,34	15,34	16,34	17,34	18,34	19,34	20,34	21,34	
10,33	11,33	12,33	13,33	14,33	15,33	16,33	17,33	18,33	19,33	20,33	21,33	
10,32	11,32	12,32	13,32	14,32	15,32	16,32	17,32	18,32	19,32	20,32	21,32	
10,31	11,31	12,31	13,31	14,31	15,31	16,31	17,31	18,31	19,31	20,31	21,31	
10,30	11,30	12,30	13,30	14,30	15,30	16,30	17,30	18,30	19,30	20,30	21,30	
10,29	11,29	12,29	13,29	14,29	15,29	16,29	17,29	18,29	19,29	20,29	21,29	
10,28	11,28	12,28	13,28	14,28	15,28	16,28	17,28	18,28	19,28	20,28	21,28	
10,27	11,27	12,27	13,27	14,27	15,27	16,27	17,27	18,27	19,27	20,27	21,27	
10,26	11,26	12,26	13,26	14,26	15,26	16,26	17,26	18,26	19,26	20,26	21,26	
10,25	11,25	12,25	13,25	14,25	15,25	16,25	17,25	18,25	19,25	20,25	21,25	
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10,22	11,22	12,22	13,22	14,22	15,22	16,22	17,22	18,22	19,22	20,22	21,22	
10,21	11,21	12,21	13,21	14,21	15,21	16,21	17,21	18,21	19,21	20,21	21,21	
10,20	11,20	12,20	13,20	14,20	15,20	16,20	17,20	18,20	19,20	20,20	21,20	
10,19	11,19	12,19	13,19	14,19	15,19	16,19	17,19	18,19	19,19	20,19	21,19	
10,18	11,18	12,18	13,18	14,18	15,18	16,18	17,18	18,18	19,18	20,18	21,18	
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10,16	11,16	12,16	13,16	14,16	15,16	16,16	17,16	18,16	19,16	20,16	21,16	
10,15	11,15	12,15	13,15	14,15	15,15	16,15	17,15	18,15	19,15	20,15	21,15	
10,14	11,14	12,14	13,14	14,14	15,14	16,14	17,14	18,14	19,14	20,14	21,14	
10,13	11,13	12,13	13,13	14,13	15,13	16,13	17,13	18,13	19,13	20,13	21,13	
10,12	11,12	12,12	13,12	14,12	15,12	16,12	17,12	18,12	19,12	20,12	21,12	
10,11	11,11	12,11	13,11	14,11	15,11	16,11	17,11	18,11	19,11	20,11	21,11	

10,10	11,10	12,10	13,10	14,10	15,10	16,10	17,10	18,10	19,10	20,10	21,10
10,9	11,9	12,9	13,9	14,9	15,9	16,9	17,9	18,9	19,9	20,9	21,9
10,8	11,8	12,8	13,8	14,8	15,8	16,8	17,8	18,8	19,8	20,8	21,8
10,7	11,7	12,7	13,7	14,7	15,7	16,7	17,7	18,7	19,7	20,7	21,7
10,6	11,6	12,6	13,6	14,6	15,6	16,6	17,6	18,6	19,6	20,6	21,6
10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5	19,5	20,5	21,5
10,4	11,4	12,4	13,4	14,4	15,4	16,4	17,4	18,4	19,4	20,4	21,4
10,3	11,3	12,3	13,3	14,3	15,3	16,3	17,3	18,3	19,3	20,3	21,3
10,2	11,2	12,2	13,2	14,2	15,2	16,2	17,2	18,2	19,2	20,2	21,2
10,1	11,1	12,1	13,1	14,1	15,1	16,1	17,1	18,1	19,1	20,1	21,1
10,South Edge	11,South Edge	12,South Edge	13,South Edge	14,South Edge	15,South Edge	16,South Edge	17,South Edge	18,South Edge	19,South Edge	20,South Edge	21,South Edge
119.501510	119.501474	119.501439	119.501404	119.501368	119.501333	119.501298	119.501262	119.501227	119.501191	119.501156	119.501124
204171.74	204171.39	204171.04	204170.70	204170.35	204170.01	204169.66	204169.31	204168.97	204168.62	204168.27	204167.96

South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradie

1@38 m

1@38 m

2@4	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5	15@5
4	5	5	5	5	5	5	5	5	5	5	5
575410	575414.5	575419.5	575424.5	575429.5	575434.5	575439.5	575444.5	575449.5	575454.5	575459.5	575464.5
22	23	24	25	26	27	28	29	30	31	32	33
22,North Edge	23,North Edge	24,North Edge	25,North Edge	26,North Edge	27,North Edge	28,North Edge	29,North Edge	30,North Edge	31,North Edge	32,North Edge	33,North Edge
22,42	23,42	24,42	25,42	26,42	27,42	28,42	29,42	30,42	31,42	32,42	33,42
22,41	23,41	24,41	25,41	26,41	27,41	28,41	29,41	30,41	31,41	32,41	33,41
22,40	23,40	24,40	25,40	26,40	27,40	28,40	29,40	30,40	31,40	32,40	33,40
22,39	23,39	24,39	25,39	26,39	27,39	28,39	29,39	30,39	31,39	32,39	33,39
22,38	23,38	24,38	25,38	26,38	27,38	28,38	29,38	30,38	31,38	32,38	33,38
22,37	23,37	24,37	25,37	26,37	27,37	28,37	29,37	30,37	31,37	32,37	33,37
22,36	23,36	24,36	25,36	26,36	27,36	28,36	29,36	30,36	31,36	32,36	33,36
22,35	23,35	24,35	25,35	26,35	27,35	28,35	29,35	30,35	31,35	32,35	33,35
22,34	23,34	24,34	25,34	26,34	27,34	28,34	29,34	30,34	31,34	32,34	33,34
22,33	23,33	24,33	25,33	26,33	27,33	28,33	29,33	30,33	31,33	32,33	33,33
22,32	23,32	24,32	25,32	26,32	27,32	28,32	29,32	30,32	31,32	32,32	33,32
22,31	23,31	24,31	25,31	26,31	27,31	28,31	29,31	30,31	31,31	32,31	33,31
22,30	23,30	24,30	25,30	26,30	27,30	28,30	29,30	30,30	31,30	32,30	33,30
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22,21	23,21	24,21	25,21	26,21	27,21	28,21	29,21	30,21	31,21	32,21	33,21
22,20	23,20	24,20	25,20	26,20	27,20	28,20	29,20	30,20	31,20	32,20	33,20
22,19	23,19	24,19	25,19	26,19	27,19	28,19	29,19	30,19	31,19	32,19	33,19
22,18	23,18	24,18	25,18	26,18	27,18	28,18	29,18	30,18	31,18	32,18	33,18
22,17	23,17	24,17	25,17	26,17	27,17	28,17	29,17	30,17	31,17	32,17	33,17
22,16	23,16	24,16	25,16	26,16	27,16	28,16	29,16	30,16	31,16	32,16	33,16
22,15	23,15	24,15	25,15	26,15	27,15	28,15	29,15	30,15	31,15	32,15	33,15
22,14	23,14	24,14	25,14	26,14	27,14	28,14	29,14	30,14	31,14	32,14	33,14
22,13	23,13	24,13	25,13	26,13	27,13	28,13	29,13	30,13	31,13	32,13	33,13
22,12	23,12	24,12	25,12	26,12	27,12	28,12	29,12	30,12	31,12	32,12	33,12
22,11	23,11	24,11	25,11	26,11	27,11	28,11	29,11	30,11	31,11	32,11	33,11

22,10	23,10	24,10	25,10	26,10	27,10	28,10	29,10	30,10	31,10	32,10	33,10
22,9	23,9	24,9	25,9	26,9	27,9	28,9	29,9	30,9	31,9	32,9	33,9
22,8	23,8	24,8	25,8	26,8	27,8	28,8	29,8	30,8	31,8	32,8	33,8
22,7	23,7	24,7	25,7	26,7	27,7	28,7	29,7	30,7	31,7	32,7	33,7
22,6	23,6	24,6	25,6	26,6	27,6	28,6	29,6	30,6	31,6	32,6	33,6
22,5	23,5	24,5	25,5	26,5	27,5	28,5	29,5	30,5	31,5	32,5	33,5
22,4	23,4	24,4	25,4	26,4	27,4	28,4	29,4	30,4	31,4	32,4	33,4
22,3	23,3	24,3	25,3	26,3	27,3	28,3	29,3	30,3	31,3	32,3	33,3
22,2	23,2	24,2	25,2	26,2	27,2	28,2	29,2	30,2	31,2	32,2	33,2
22,1	23,1	24,1	25,1	26,1	27,1	28,1	29,1	30,1	31,1	32,1	33,1
22,South Edge	23,South Edge	24,South Edge	25,South Edge	26,South Edge	27,South Edge	28,South Edge	29,South Edge	30,South Edge	31,South Edge	32,South Edge	33,South Edge
119.501096	119.501064	119.501029	119.500993	119.500958	119.500923	119.500887	119.500852	119.500817	119.500781	119.500746	119.500711
204167.69	204167.37	204167.03	204166.68	204166.34	204165.99	204165.64	204165.30	204164.95	204164.60	204164.26	204163.91

South,Hydraulic Gradie South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradie South,Hydraulic Gradie South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi

Aquifer defined to be 11 m below arbitrary SS WLE
with uniform K, with water table at top of k=11.
AX Farm model boundary conditions specified independent of A Farm.

SE node WLE (m)	119.5		
gradient	1.00E-05	K (m/d)	1750
direction	S of E	d/yr	365.2425
degrees	45		
gradient_i	-7.07107E-06	q_i (m/yr)	4.51965
gradient_j	7.07107E-06	q_j (m/yr)	-4.51965

dP/dh from STOMP User's Guide-->
implied local g consistent with metro Seattle
Not used:

NIST webbook rho @	998.207	kg/m3
standard g	9.80665	m/s2

dP/dh (Pa/m) = rho*	-9793.5192
Patm (Pa)	101325
base elev (m)	108.5
k=1 node elev (m)	109.0

15@5	15@5	15@5	15@5	1@7	1@11	1@16	1@25	1@38	East Edge	BC WLE (m)	BC k=1 Pressure (Pa)
5	5	5	5	7	11	16	25	38	East Edge	BC WLE (m)	BC k=1 Pressure (Pa)
575469.5	575474.5	575479.5	575484.5	575490.5	575499.5	575513	575533.5	575565	575584	BC WLE (m)	BC k=1 Pressure (Pa)
34	35	36	37	38	39	40	41	42	East Edge	BC WLE (m)	BC k=1 Pressure (Pa)
34,North Edge	35,North Edge	36,North Edge	37,North Edge	38,North Edge	39,North Edge	40,North Edge	41,North Edge	42,North Edge	East Edge,North Edge		
34,42	35,42	36,42	37,42	38,42	39,42	40,42	41,42	42,42	East Edge,42	119.502242	204178.90
34,41	35,41	36,41	37,41	38,41	39,41	40,41	41,41	42,41	East Edge,41	119.502019	204176.72
34,40	35,40	36,40	37,40	38,40	39,40	40,40	41,40	42,40	East Edge,40	119.501874	204175.30
34,39	35,39	36,39	37,39	38,39	39,39	40,39	41,39	42,39	East Edge,39	119.501778	204174.37
34,38	35,38	36,38	37,38	38,38	39,38	40,38	41,38	42,38	East Edge,38	119.501715	204173.74
34,37	35,37	36,37	37,37	38,37	39,37	40,37	41,37	42,37	East Edge,37	119.501672	204173.33
34,36	35,36	36,36	37,36	38,36	39,36	40,36	41,36	42,36	East Edge,36	119.501637	204172.98
34,35	35,35	36,35	37,35	38,35	39,35	40,35	41,35	42,35	East Edge,35	119.501602	204172.64
34,34	35,34	36,34	37,34	38,34	39,34	40,34	41,34	42,34	East Edge,34	119.501566	204172.29
34,33	35,33	36,33	37,33	38,33	39,33	40,33	41,33	42,33	East Edge,33	119.501531	204171.94
34,32	35,32	36,32	37,32	38,32	39,32	40,32	41,32	42,32	East Edge,32	119.501496	204171.60
34,31	35,31	36,31	37,31	38,31	39,31	40,31	41,31	42,31	East Edge,31	119.501460	204171.25
34,30	35,30	36,30	37,30	38,30	39,30	40,30	41,30	42,30	East Edge,30	119.501425	204170.91
34,29	35,29	36,29	37,29	38,29	39,29	40,29	41,29	42,29	East Edge,29	119.501389	204170.56
34,28	35,28	36,28	37,28	38,28	39,28	40,28	41,28	42,28	East Edge,28	119.501354	204170.21
34,27	35,27	36,27	37,27	38,27	39,27	40,27	41,27	42,27	East Edge,27	119.501319	204169.87
34,26	35,26	36,26	37,26	38,26	39,26	40,26	41,26	42,26	East Edge,26	119.501283	204169.52
34,25	35,25	36,25	37,25	38,25	39,25	40,25	41,25	42,25	East Edge,25	119.501248	204169.17
34,24	35,24	36,24	37,24	38,24	39,24	40,24	41,24	42,24	East Edge,24	119.501213	204168.83
34,23	35,23	36,23	37,23	38,23	39,23	40,23	41,23	42,23	East Edge,23	119.501177	204168.48
34,22	35,22	36,22	37,22	38,22	39,22	40,22	41,22	42,22	East Edge,22	119.501140	204168.12
34,21	35,21	36,21	37,21	38,21	39,21	40,21	41,21	42,21	East Edge,21	119.501101	204167.74
34,20	35,20	36,20	37,20	38,20	39,20	40,20	41,20	42,20	East Edge,20	119.501064	204167.37
34,19	35,19	36,19	37,19	38,19	39,19	40,19	41,19	42,19	East Edge,19	119.501029	204167.03
34,18	35,18	36,18	37,18	38,18	39,18	40,18	41,18	42,18	East Edge,18	119.500993	204166.68
34,17	35,17	36,17	37,17	38,17	39,17	40,17	41,17	42,17	East Edge,17	119.500958	204166.34
34,16	35,16	36,16	37,16	38,16	39,16	40,16	41,16	42,16	East Edge,16	119.500923	204165.99
34,15	35,15	36,15	37,15	38,15	39,15	40,15	41,15	42,15	East Edge,15	119.500887	204165.64
34,14	35,14	36,14	37,14	38,14	39,14	40,14	41,14	42,14	East Edge,14	119.500852	204165.30
34,13	35,13	36,13	37,13	38,13	39,13	40,13	41,13	42,13	East Edge,13	119.500817	204164.95
34,12	35,12	36,12	37,12	38,12	39,12	40,12	41,12	42,12	East Edge,12	119.500781	204164.60
34,11	35,11	36,11	37,11	38,11	39,11	40,11	41,11	42,11	East Edge,11	119.500746	204164.26

34,10	35,10	36,10	37,10	38,10	39,10	40,10	41,10	42,10	East Edge,10	119.500711	204163.91
34,9	35,9	36,9	37,9	38,9	39,9	40,9	41,9	42,9	East Edge,9	119.500675	204163.57
34,8	35,8	36,8	37,8	38,8	39,8	40,8	41,8	42,8	East Edge,8	119.500640	204163.22
34,7	35,7	36,7	37,7	38,7	39,7	40,7	41,7	42,7	East Edge,7	119.500605	204162.87
34,6	35,6	36,6	37,6	38,6	39,6	40,6	41,6	42,6	East Edge,6	119.500569	204162.53
34,5	35,5	36,5	37,5	38,5	39,5	40,5	41,5	42,5	East Edge,5	119.500527	204162.11
34,4	35,4	36,4	37,4	38,4	39,4	40,4	41,4	42,4	East Edge,4	119.500463	204161.49
34,3	35,3	36,3	37,3	38,3	39,3	40,3	41,3	42,3	East Edge,3	119.500368	204160.55
34,2	35,2	36,2	37,2	38,2	39,2	40,2	41,2	42,2	East Edge,2	119.500223	204159.13
34,1	35,1	36,1	37,1	38,1	39,1	40,1	41,1	42,1	East Edge,1	119.500000	204156.95
34,South Edge	35,South Edge	36,South Edge	37,South Edge	38,South Edge	39,South Edge	40,South Edge	41,South Edge	42,South Edge	East Edge,South Edge		
119.500675	119.500640	119.500605	119.500569	119.500527	119.500463	119.500368	119.500223	119.500000			
204163.57	204163.22	204162.87	204162.53	204162.11	204161.49	204160.55	204159.13	204156.95			

South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradi South,Hydraulic Gradient,Outflow,endl,42,42,1,1,1,11,1,endl,0,yr,204156.95,Pa,,,

Boundary Conditions:

West,Neumann,Outflow,endl,1,1,1,42,1,11,1,endl,0,yr,4.51965,m/yr,,,
North,Neumann,Outflow,endl,1,42,42,42,1,11,1,endl,0,yr,-4.51965,m/yr,,,

East,Hydraulic Gradient,Outflow,endl,42,42,42,42,1,11,1,endl,0,yr,204178.9,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,41,41,1,11,1,endl,0,yr,204176.72,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,40,40,1,11,1,endl,0,yr,204175.3,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,39,39,1,11,1,endl,0,yr,204174.37,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,38,38,1,11,1,endl,0,yr,204173.74,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,37,37,1,11,1,endl,0,yr,204173.33,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,36,36,1,11,1,endl,0,yr,204172.98,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,35,35,1,11,1,endl,0,yr,204172.64,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,34,34,1,11,1,endl,0,yr,204172.29,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,33,33,1,11,1,endl,0,yr,204171.94,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,32,32,1,11,1,endl,0,yr,204171.6,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,31,31,1,11,1,endl,0,yr,204171.25,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,30,30,1,11,1,endl,0,yr,204170.91,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,29,29,1,11,1,endl,0,yr,204170.56,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,28,28,1,11,1,endl,0,yr,204170.21,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,27,27,1,11,1,endl,0,yr,204169.87,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,26,26,1,11,1,endl,0,yr,204169.52,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,25,25,1,11,1,endl,0,yr,204169.17,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,24,24,1,11,1,endl,0,yr,204168.83,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,23,23,1,11,1,endl,0,yr,204168.48,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,22,22,1,11,1,endl,0,yr,204168.12,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,21,21,1,11,1,endl,0,yr,204167.74,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,20,20,1,11,1,endl,0,yr,204167.37,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,19,19,1,11,1,endl,0,yr,204167.03,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,18,18,1,11,1,endl,0,yr,204166.68,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,17,17,1,11,1,endl,0,yr,204166.34,Pa,,,
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East,Hydraulic Gradient,Outflow,endl,42,42,15,15,1,11,1,endl,0,yr,204165.64,Pa,,,
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East,Hydraulic Gradient,Outflow,endl,42,42,13,13,1,11,1,endl,0,yr,204164.95,Pa,,,
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East,Hydraulic Gradient,Outflow,endl,42,42,11,11,1,11,1,endl,0,yr,204164.26,Pa,,,

East,Hydraulic Gradient,Outflow,endl,42,42,10,10,1,11,1,endl,0,yr,204163.91,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,9,9,1,11,1,endl,0,yr,204163.57,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,8,8,1,11,1,endl,0,yr,204163.22,Pa,,,
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East,Hydraulic Gradient,Outflow,endl,42,42,6,6,1,11,1,endl,0,yr,204162.53,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,5,5,1,11,1,endl,0,yr,204162.11,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,4,4,1,11,1,endl,0,yr,204161.49,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,3,3,1,11,1,endl,0,yr,204160.55,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,2,2,1,11,1,endl,0,yr,204159.13,Pa,,,
East,Hydraulic Gradient,Outflow,endl,42,42,1,1,1,11,1,endl,0,yr,204156.95,Pa,,,

South,Hydraulic Gradient,Outflow,endl,1,1,1,1,1,11,1,endl,0,yr,204178.7,Pa,,,
South,Hydraulic Gradient,Outflow,endl,2,2,1,1,1,11,1,endl,0,yr,204176.51,Pa,,,
South,Hydraulic Gradient,Outflow,endl,3,3,1,1,1,11,1,endl,0,yr,204175.1,Pa,,,
South,Hydraulic Gradient,Outflow,endl,4,4,1,1,1,11,1,endl,0,yr,204174.16,Pa,,,
South,Hydraulic Gradient,Outflow,endl,5,5,1,1,1,11,1,endl,0,yr,204173.54,Pa,,,
South,Hydraulic Gradient,Outflow,endl,6,6,1,1,1,11,1,endl,0,yr,204173.12,Pa,,,
South,Hydraulic Gradient,Outflow,endl,7,7,1,1,1,11,1,endl,0,yr,204172.78,Pa,,,
South,Hydraulic Gradient,Outflow,endl,8,8,1,1,1,11,1,endl,0,yr,204172.43,Pa,,,
South,Hydraulic Gradient,Outflow,endl,9,9,1,1,1,11,1,endl,0,yr,204172.08,Pa,,,
South,Hydraulic Gradient,Outflow,endl,10,10,1,1,1,11,1,endl,0,yr,204171.74,Pa,,,
South,Hydraulic Gradient,Outflow,endl,11,11,1,1,1,11,1,endl,0,yr,204171.39,Pa,,,
South,Hydraulic Gradient,Outflow,endl,12,12,1,1,1,11,1,endl,0,yr,204171.04,Pa,,,
South,Hydraulic Gradient,Outflow,endl,13,13,1,1,1,11,1,endl,0,yr,204170.7,Pa,,,
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South,Hydraulic Gradient,Outflow,endl,15,15,1,1,1,11,1,endl,0,yr,204170.01,Pa,,,
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South,Hydraulic Gradient,Outflow,endl,17,17,1,1,1,11,1,endl,0,yr,204169.31,Pa,,,
South,Hydraulic Gradient,Outflow,endl,18,18,1,1,1,11,1,endl,0,yr,204168.97,Pa,,,
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South,Hydraulic Gradient,Outflow,endl,21,21,1,1,1,11,1,endl,0,yr,204167.96,Pa,,,
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South,Hydraulic Gradient,Outflow,endl,23,23,1,1,1,11,1,endl,0,yr,204167.37,Pa,,,
South,Hydraulic Gradient,Outflow,endl,24,24,1,1,1,11,1,endl,0,yr,204167.03,Pa,,,
South,Hydraulic Gradient,Outflow,endl,25,25,1,1,1,11,1,endl,0,yr,204166.68,Pa,,,
South,Hydraulic Gradient,Outflow,endl,26,26,1,1,1,11,1,endl,0,yr,204166.34,Pa,,,
South,Hydraulic Gradient,Outflow,endl,27,27,1,1,1,11,1,endl,0,yr,204165.99,Pa,,,
South,Hydraulic Gradient,Outflow,endl,28,28,1,1,1,11,1,endl,0,yr,204165.64,Pa,,,
South,Hydraulic Gradient,Outflow,endl,29,29,1,1,1,11,1,endl,0,yr,204165.3,Pa,,,
South,Hydraulic Gradient,Outflow,endl,30,30,1,1,1,11,1,endl,0,yr,204164.95,Pa,,,
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South,Hydraulic Gradient,Outflow,endl,36,36,1,1,1,11,1,endl,0,yr,204162.87,Pa,,,
South,Hydraulic Gradient,Outflow,endl,37,37,1,1,1,11,1,endl,0,yr,204162.53,Pa,,,
South,Hydraulic Gradient,Outflow,endl,38,38,1,1,1,11,1,endl,0,yr,204162.11,Pa,,,
South,Hydraulic Gradient,Outflow,endl,39,39,1,1,1,11,1,endl,0,yr,204161.49,Pa,,,
South,Hydraulic Gradient,Outflow,endl,40,40,1,1,1,11,1,endl,0,yr,204160.55,Pa,,,

select destination range, define transpose, CTRL+SHIFT+ENTER

South,Hydraulic Gradient,Outflow,endl,41,41,1,1,1,11,1,endl,0,yr,204159.13,Pa,,,
South,Hydraulic Gradient,Outflow,endl,42,42,1,1,1,11,1,endl,0,yr,204156.95,Pa,,,

ATTACHMENT 2

RE-CALCULATION OF NITRITE AND NITRATE SOURCE RELEASE TERMS

Workbook File	Attachment_2_RPP-CALC_60497.xlsx
Workbook Creator	Arun Wahi (INTERA, Inc.) HID#H0396269
Date Originally Created	9/22/2015
Workbook Purpose	This workbook documents re-calculation of separate source release terms for nitrite and nitrate for the WMA A/AX TWRWP models in RPP-CALC-60497 from input files in the Final TC&WM EIS.

SPREADSHEET NAME	DESCRIPTION	CREATED BY	LAST DATE UPDATED
Workbook Notes	Summary-level notes related to this workbook	Arun Wahi (INTERA)	9/22/2015
Inventory-rate_conversion	Calculates uniform rates of release for unit inventories (1 Ci or 1 kg) and for 4,000-gallon releases over 16-node tank footprints for 1-year duration.	Arun Wahi (INTERA)	9/22/2015
NO3_NO2_molar_mass	Contains molar masses of nitrite and nitrate used in stoichiometric calculations.	Arun Wahi (INTERA)	9/22/2015
PL_references	Integrates release rates of random contaminants from TC&WM EIS input files for A Farm past leaks to determine total inventories and indicates reference documents with consistent inventories. The reference document inventories for nitrite in A Farm past leaks are used directly, whereas all other nitrite inventories are estimated as fractions of the TC&WM EIS nitrate inventories.	Arun Wahi (INTERA)	9/22/2015
TR_and_AE_from_data_pkg	Contains contaminant inventories for SSTs in WMA A/AX from DOE/ORP-2003-02 Rev. 0 that were used in the EIS and calculates nitrite and nitrate fractions for each tank farm overall on a nitrate basis.	Arun Wahi (INTERA)	9/22/2015
AX_AE_NO3_NO2	Spreadsheets used to perform stoichiometric calculations to split nitrate source release terms from the TC&WM EIS input into separate nitrite and nitrate terms for tanks in AX farm.	Arun Wahi (INTERA)	9/22/2015
AX_TR_NO3_NO2		Arun Wahi (INTERA)	9/22/2015
AX_TR_NO3_NO2		Arun Wahi (INTERA)	9/22/2015
AX_PL_NO3_NO2		Arun Wahi (INTERA)	9/22/2015
A_AE_NO3_NO2	Spreadsheets used to perform stoichiometric calculations to split nitrate source release terms from the TC&WM EIS input into separate nitrite and nitrate terms for tanks in A farm	Arun Wahi (INTERA)	9/22/2015
A_TR_NO3_NO2		Arun Wahi (INTERA)	9/22/2015
A_RL_NO3_NO2		Arun Wahi (INTERA)	9/22/2015
A_PL_NO3_NO2		Arun Wahi (INTERA)	9/22/2015

RL or PL release time (yr)	d/yr	s/d	RL or PL release time (s)	Nodes in release footprint	Unit release rate per node (Ci/s or kg/s)
1	365.25	86400	31557600	16	1.98051E-09

Check:	EIS AX RL Cr Inventory (kg)	EIS release per node per s (kg/s)	Nodes in EIS AX release footprint	Equivalent unit release over tank footprint (kg/s)
	4.390E+01	1.391107E-08	100	1.98051E-09

RL volume per tank (gal)	L/gal	RL volume per tank (m^3)	Release rate per node (m^3/s)
4000	3.78541	15.14164	2.99881E-08

M(N)	14.0067	g/mol	CRC Handbook 92nd Edition (2011-2012)
M(O)	15.9994	g/mol	CRC Handbook 92nd Edition (2011-2012)
M(NO3)	62.0049	g/mol	
M(NO2)	46.0055	g/mol	

Past Leaks check to confirm data sources:

	EIS input release rate	units	equivalent inventory	units	Reference Matched
A-103					
H2O	4.119451E-08	L/s	5.495E+03	gallons	Field and Jones (2005)
Cr	3.226243E-10	kg/s	1.63E-01	kg	?
Hg	6.656479E-11	kg/s	3.36E-02	kg	?
Pb	1.959512E-11	kg/s	9.89E-03	kg	?
A-104					
H2O		L/s	0.000E+00	gallons	
Cr	1.324958E-08	kg/s	6.69E+00	kg	Wood et al. (2003)
Hg	1.105122E-12	kg/s	5.58E-04	kg	Wood et al. (2003)
Pb	1.857714E-10	kg/s	9.38E-02	kg	Wood et al. (2003)
A-105					
H2O		L/s	0.000E+00	gallons	
Cr	3.149004E-09	kg/s	1.59E+00	kg	SIM (2005)
Hg	2.277581E-12	kg/s	1.15E-03	kg	SIM (2005)
Pb	8.100267E-10	kg/s	4.09E-01	kg	SIM (2005)

Analyte	Units	A-101	A-102	A-103	A-104	A-105	A-106
Al	kg	8.82E+04	7.33E+03	4.43E+04	8.07E+03	8.28E+03	1.47E+04
Bi	kg	2.63E+02	6.13E+01	1.39E+02	2.06E-01	0.00E+00	1.18E+02
Ca	kg	9.83E+02	1.23E+02	2.49E+03	1.74E+03	1.95E+03	3.39E+03
Cl	kg	1.45E+04	1.42E+03	1.01E+04	5.93E+01	7.79E+01	4.05E+03
Cr	kg	8.54E+03	1.56E+03	2.25E+03	9.01E+01	5.18E+02	3.26E+03
F	kg	1.40E+03	1.03E+02	2.07E+03	1.35E+00	2.51E+01	1.41E+02
Fe	kg	1.56E+03	3.47E+03	1.40E+03	2.95E+04	1.92E+04	1.70E+04
Hg	kg	4.22E+00	0.00E+00	3.74E+00	4.95E+01	6.48E+01	3.69E+01
K	kg	1.14E+04	7.84E+02	5.42E+03	2.74E+01	7.24E+01	1.45E+03
La	kg	1.47E+02	1.83E+01	8.80E+01	1.05E+01	3.66E+02	5.24E+01
Mn	kg	2.36E+02	5.99E+02	1.43E+02	4.13E+03	6.49E+02	9.11E+02
Na	kg	6.60E+05	3.12E+04	3.78E+05	1.42E+04	5.50E+04	7.85E+04
Ni	kg	4.19E+02	7.43E+01	2.28E+02	8.98E+02	2.32E+03	4.02E+02
NO2	kg	2.67E+05	1.48E+04	1.52E+05	3.01E+03	5.57E+02	4.23E+04
NO3	kg	4.50E+05	2.14E+04	2.29E+05	4.10E+02	1.42E+04	5.03E+04
Pb	kg	5.02E+02	2.66E+02	2.03E+02	6.74E+01	2.31E+03	6.72E+02
PO4	kg	1.59E+04	1.11E+03	1.06E+04	4.17E+02	7.94E+03	3.46E+04
Si	kg	2.29E+03	6.98E+02	1.57E+04	2.47E+03	4.86E+03	2.47E+04
SO4	kg	6.08E+04	4.87E+03	3.14E+04	8.76E+02	7.36E+03	2.28E+03
Sr	kg	5.22E+01	5.57E+00	1.68E+01	6.91E+01	7.63E+01	3.35E+01
TIC as CO3	kg	2.32E+05	4.91E+03	1.21E+05	1.87E+03	1.74E+04	1.10E+04
TOC	kg	1.85E+04	3.04E+03	1.39E+04	0.00E+00	0.00E+00	4.31E+03
UTOTAL	kg	2.13E+03	6.24E+03	2.02E+03	5.96E+01	2.57E+00	5.18E+02
Zr	kg	1.72E+02	8.63E+01	2.78E+02	2.83E+01	9.83E+02	7.76E+02
106Ru	Ci	2.36E-04	1.16E-05	8.23E-05	4.67E-05	4.25E-04	2.36E-03
113mCd	Ci	1.82E+02	1.05E+01	7.48E+01	2.91E+01	6.35E+02	2.63E+02
125Sb	Ci	7.80E+01	5.78E+00	4.07E+01	4.99E+02	6.44E+01	6.43E+00
126Sn	Ci	6.18E+00	3.25E-01	2.55E+00	4.16E+00	2.81E+01	2.68E+01
129I	Ci	6.27E-01	4.15E-02	6.19E-02	1.92E-02	1.32E-01	6.31E-02
134Cs	Ci	5.40E-01	4.52E-02	3.17E-01	5.31E+00	3.00E-01	1.35E-01
137Cs	Ci	6.35E+05	4.23E+04	3.10E+05	6.63E+04	1.15E+05	6.88E+04
137mBa	Ci	6.01E+05	4.00E+04	2.93E+05	6.28E+04	1.09E+05	6.51E+04
14C	Ci	6.61E+01	1.71E+00	4.02E+00	1.40E+00	9.60E+00	5.18E-01
151Sm	Ci	3.43E+04	1.79E+03	1.41E+04	2.33E+04	1.59E+05	1.48E+05
152Eu	Ci	9.58E+00	5.41E-01	4.22E+00	6.32E+00	3.59E+01	2.89E+01
154Eu	Ci	4.24E+02	6.16E+01	4.34E+02	1.65E+03	3.68E+03	5.23E+02
155Eu	Ci	2.09E+02	1.70E+01	1.34E+02	2.28E+02	8.99E+02	9.59E+02
226Ra	Ci	4.83E-04	2.16E-05	2.09E-04	8.15E-04	2.98E-03	5.07E-03
227Ac	Ci	4.26E-03	1.27E-04	1.22E-03	4.68E-03	2.01E-02	2.19E-02
228Ra	Ci	3.48E-01	4.75E-02	3.34E-01	4.56E-05	1.44E-08	3.55E-02
229Th	Ci	1.48E-02	1.10E-03	7.76E-03	3.92E-05	4.20E-06	8.57E-04
231Pa	Ci	1.03E-02	5.94E-04	4.59E-03	6.28E-03	3.63E-02	3.93E-02
232Th	Ci	7.76E-02	5.80E-03	4.08E-02	9.12E-06	2.44E-09	4.33E-03
232U	Ci	1.13E+00	3.59E+00	1.16E+00	5.01E-03	6.68E-08	2.04E-01
233U	Ci	4.63E+00	1.47E+01	4.75E+00	2.07E-02	1.69E-09	8.37E-01
234U	Ci	7.96E-01	2.34E+00	7.57E-01	2.06E-02	8.81E-04	1.91E-01
235U	Ci	3.16E-02	9.28E-02	3.00E-02	8.53E-04	3.67E-05	7.69E-03
236U	Ci	2.56E-02	7.60E-02	2.44E-02	5.64E-04	2.40E-05	6.11E-03
237Np	Ci	1.14E+00	1.02E-01	7.09E-01	2.91E-02	1.45E-01	7.08E-02
238Pu	Ci	4.44E+00	1.16E+01	5.58E+00	1.24E+01	2.13E+01	3.76E+01

238U	Ci	7.11E-01	2.08E+00	6.73E-01	1.99E-02	8.58E-04	1.73E-01
239Pu	Ci	1.47E+02	3.31E+02	1.96E+02	6.94E+02	5.82E+02	1.07E+03
240Pu	Ci	2.61E+01	6.14E+01	3.38E+01	1.08E+02	1.11E+02	1.99E+02
241Am	Ci	4.09E+02	2.50E+02	1.83E+02	3.91E+02	4.08E+03	5.77E+02
241Pu	Ci	2.35E+02	6.19E+02	2.92E+02	6.80E+02	1.14E+03	2.01E+03
242Cm	Ci	5.42E-01	2.16E-01	4.03E-01	2.95E-01	3.66E+00	4.41E-01
242Pu	Ci	1.82E-03	5.10E-03	2.24E-03	4.16E-03	9.25E-03	1.66E-02
243Am	Ci	1.32E-02	1.25E-02	6.13E-03	7.92E-03	1.27E-01	2.60E-02
243Cm	Ci	3.97E-02	1.71E-02	3.13E-02	1.66E-02	2.46E-01	3.35E-02
244Cm	Ci	6.67E-01	5.57E-01	2.29E-01	2.86E-01	6.85E+00	1.14E+00
3H	Ci	1.70E+02	1.50E+01	1.05E+02	1.34E+00	3.48E+01	1.17E+01
59Ni	Ci	7.44E+00	3.13E-01	3.10E+00	1.28E+01	4.75E+01	7.60E+01
60Co	Ci	4.94E+01	2.76E+01	1.81E+01	4.95E+02	5.27E+00	3.83E+00
63Ni	Ci	7.07E+02	2.97E+01	2.92E+02	1.19E+03	4.53E+03	7.10E+03
79Se	Ci	1.01E+00	5.38E-02	4.19E-01	6.44E-01	4.50E+00	4.17E+00
90Sr	Ci	1.74E+05	8.55E+04	1.23E+05	2.49E+06	3.12E+06	5.28E+05
90Y	Ci	1.74E+05	8.55E+04	1.23E+05	2.49E+06	3.12E+06	5.28E+05
93mNb	Ci	3.96E+01	1.91E+00	1.50E+01	2.50E+01	1.71E+02	1.62E+02
93Zr	Ci	4.90E+01	2.66E+00	2.04E+01	2.76E+01	2.07E+02	1.80E+02
99Tc	Ci	3.25E+02	3.70E+01	1.62E+02	9.91E+00	6.79E+01	7.21E+01

A Farm Total	TR = 1% A Farm Total	Nitrate Fraction	EIS TR input
1.71E+05	1.71E+03		
5.82E+02	5.82E+00		
1.07E+04	1.07E+02		
3.02E+04	3.02E+02		
1.62E+04	1.62E+02		1.620E+02
3.74E+03	3.74E+01		
7.21E+04	7.21E+02		
1.59E+02	1.59E+00		1.590E+00
1.92E+04	1.92E+02		
6.82E+02	6.82E+00		
6.67E+03	6.67E+01		
1.22E+06	1.22E+04		
4.34E+03	4.34E+01		
4.80E+05	4.80E+03	4.57916E-01	
7.65E+05	7.65E+03	5.42084E-01	1.410E+04
4.02E+03	4.02E+01		4.020E+01
7.06E+04	7.06E+02		
5.07E+04	5.07E+02		
1.08E+05	1.08E+03		
2.53E+02	2.53E+00		
3.88E+05	3.88E+03		
3.98E+04	3.98E+02		
1.10E+04	1.10E+02		1.100E+02
2.32E+03	2.32E+01		
3.16E-03	3.16E-05		
1.19E+03	1.19E+01		
6.94E+02	6.94E+00		
6.81E+01	6.81E-01		
9.45E-01	9.45E-03		
6.65E+00	6.65E-02		
1.24E+06	1.24E+04		
1.17E+06	1.17E+04		
8.33E+01	8.33E-01		
3.80E+05	3.80E+03		
8.55E+01	8.55E-01		
6.77E+03	6.77E+01		
2.45E+03	2.45E+01		
9.58E-03	9.58E-05		
5.23E-02	5.23E-04		
7.65E-01	7.65E-03		
2.46E-02	2.46E-04		
9.74E-02	9.74E-04		
1.29E-01	1.29E-03		
6.09E+00	6.09E-02		
2.49E+01	2.49E-01		
4.11E+00	4.11E-02		
1.63E-01	1.63E-03		
1.33E-01	1.33E-03		
2.20E+00	2.20E-02		
9.29E+01	9.29E-01		

3.66E+00	3.66E-02		
3.02E+03	3.02E+01		
5.39E+02	5.39E+00		
5.89E+03	5.89E+01		
4.98E+03	4.98E+01		
5.56E+00	5.56E-02		
3.92E-02	3.92E-04		
1.93E-01	1.93E-03		
3.84E-01	3.84E-03		
9.73E+00	9.73E-02		
3.38E+02	3.38E+00		
1.47E+02	1.47E+00		
5.99E+02	5.99E+00		
1.38E+04	1.38E+02		
1.08E+01	1.08E-01		
6.52E+06	6.52E+04		
6.52E+06	6.52E+04		
4.15E+02	4.15E+00		
4.87E+02	4.87E+00		
6.74E+02	6.74E+00		

EIS AE input	AE/TR ratio	AE		AX-101	AX-102
		8.40E+02		5.44E+04	4.62E+03
		2.86E+00		1.28E+02	7.00E+00
		5.25E+01		8.21E+02	2.41E+02
		1.49E+02		9.24E+03	1.30E+02
7.970E+01	4.920E-01	7.98E+01		5.43E+03	1.86E+02
		1.84E+01		1.44E+03	3.58E+01
		3.55E+02		1.20E+03	3.41E+03
7.830E-01	4.925E-01	7.83E-01		0.00E+00	1.44E+01
		9.42E+01		7.92E+03	2.10E+02
		3.36E+00		6.35E+01	4.20E+00
		3.28E+01		6.02E+01	3.01E+02
		5.99E+03		4.83E+05	2.58E+04
		2.14E+01		1.75E+02	1.70E+03
		2.36E+03		1.78E+05	5.42E+03
6.940E+03	4.922E-01	3.76E+03		3.45E+05	3.26E+04
1.980E+01	4.925E-01	1.98E+01		2.00E+02	2.80E+01
		3.47E+02		8.93E+03	2.84E+02
		2.49E+02		9.86E+02	8.21E+02
		5.29E+02		5.27E+04	6.34E+02
		1.25E+00		1.50E+01	7.34E-01
		1.91E+03		2.02E+05	1.16E+04
		1.96E+02		1.12E+04	7.60E+03
5.390E+01	4.900E-01	5.40E+01		9.95E+02	6.96E+01
		1.14E+01		5.51E+01	5.80E+00
				3.56E-04	3.11E-04
				1.35E+02	6.88E+00
				6.08E+01	8.18E+02
				5.81E+00	2.18E-01
4.64E-03	4.91E-01			2.90E-01	1.69E-02
				2.85E-01	1.60E-02
				4.52E+05	4.08E+04
				4.27E+05	3.86E+04
4.04E-01	4.84E-01			4.64E+01	2.81E+00
				3.21E+04	1.20E+03
				8.13E+00	2.82E+00
				6.94E+02	8.72E+01
				2.59E+02	6.07E+02
				6.76E-04	1.61E-04
				4.87E-03	6.00E-04
				2.73E-01	3.02E-02
				1.16E-02	7.01E-04
				9.72E-03	3.93E-04
				6.09E-02	3.68E-03
				5.69E-01	3.08E-02
				2.33E+00	1.26E-01
				3.74E-01	2.59E-02
				1.48E-02	1.04E-03
				1.21E-02	8.47E-04
1.08E-02	4.92E-01			5.30E-01	3.09E-02
				6.77E+00	1.83E+01

1.62E-01	4.43E+00			3.32E-01	2.32E-02
				1.95E+02	2.40E+02
				3.61E+01	6.21E+01
				2.30E+02	1.10E+02
				3.62E+02	2.63E+02
				2.30E-01	1.82E-01
				2.97E-03	1.03E-02
				1.11E-02	8.07E-03
				1.80E-02	1.69E-02
				5.03E-01	4.09E-01
1.18E+00	3.49E-01			7.87E+01	4.75E+00
				1.04E+01	4.66E+00
				4.04E+01	1.49E+02
				9.74E+02	4.39E+02
				9.38E-01	3.59E-02
				1.61E+05	2.32E+05
				1.61E+05	2.32E+05
				3.69E+01	1.28E+00
				4.40E+01	1.77E+00
3.31E+00	4.91E-01			1.50E+02	8.76E+00

AX-103	AX-104	AX Farm Total	TR = 1% AX Farm Total	Nitrate Fraction
1.52E+04	2.67E+03	7.69E+04	7.69E+02	
2.66E+01	0.00E+00	1.62E+02	1.62E+00	
3.46E+02	6.10E+02	2.02E+03	2.02E+01	
3.02E+03	1.58E+01	1.24E+04	1.24E+02	
2.22E+03	2.91E+01	7.87E+03	7.87E+01	
8.20E+02	5.09E+00	2.30E+03	2.30E+01	
4.54E+03	1.37E+04	2.29E+04	2.29E+02	
1.40E+01	1.43E+01	4.27E+01	4.27E-01	
2.07E+03	1.60E+01	1.02E+04	1.02E+02	
9.09E+01	7.41E+01	2.33E+02	2.33E+00	
6.17E+02	2.36E+02	1.21E+03	1.21E+01	
1.10E+05	2.17E+03	6.21E+05	6.21E+03	
2.71E+02	7.36E+02	2.88E+03	2.88E+01	
5.30E+04	1.13E+02	2.37E+05	2.37E+03	4.17600E-01
6.47E+04	2.30E+03	4.45E+05	4.45E+03	5.82400E-01
5.67E+02	4.67E+02	1.26E+03	1.26E+01	
3.27E+03	1.26E+02	1.26E+04	1.26E+02	
1.16E+03	4.37E+01	3.01E+03	3.01E+01	
1.09E+04	2.39E+02	6.45E+04	6.45E+02	
5.37E+01	4.80E+01	1.17E+02	1.17E+00	
3.36E+04	3.86E+03	2.51E+05	2.51E+03	
4.37E+03	0.00E+00	2.32E+04	2.32E+02	
2.49E+02	1.65E+02	1.48E+03	1.48E+01	
2.20E+02	1.99E+02	4.80E+02	4.80E+00	
2.95E-04	2.77E-04	1.24E-03	1.24E-05	
1.60E+02	1.41E+02	4.43E+02	4.43E+00	
6.29E+01	2.28E+00	9.44E+02	9.44E+00	
6.77E+00	6.22E+00	1.90E+01	1.90E-01	
1.45E-01	2.91E-02	4.81E-01	4.81E-03	
1.77E-01	6.65E-02	5.45E-01	5.45E-03	
1.12E+05	5.33E+04	6.58E+05	6.58E+03	
1.06E+05	5.05E+04	6.22E+05	6.22E+03	
1.31E+01	2.12E+00	6.44E+01	6.44E-01	
3.82E+04	3.52E+04	1.07E+05	1.07E+03	
8.92E+00	7.94E+00	2.78E+01	2.78E-01	
2.54E+03	1.12E+03	4.44E+03	4.44E+01	
3.46E+02	7.93E+02	2.01E+03	2.01E+01	
6.89E-04	6.59E-04	2.19E-03	2.19E-05	
4.62E-03	4.46E-03	1.46E-02	1.46E-04	
1.03E-01	3.19E-09	4.06E-01	4.06E-03	
2.40E-03	9.30E-07	1.47E-02	1.47E-04	
9.13E-03	8.04E-03	2.73E-02	2.73E-04	
2.06E-03	5.39E-10	6.66E-02	6.66E-04	
9.11E-02	4.30E-06	6.91E-01	6.91E-03	
9.21E-02	1.08E-07	2.55E+00	2.55E-02	
1.22E-01	5.67E-02	5.79E-01	5.79E-03	
3.55E-03	2.36E-03	2.18E-02	2.18E-04	
4.19E-03	1.55E-03	1.87E-02	1.87E-04	
1.90E-01	3.22E-02	7.83E-01	7.83E-03	
3.47E+00	1.03E+01	3.88E+01	3.88E-01	

8.33E-02	5.52E-02	4.94E-01	4.94E-03	
9.53E+01	2.82E+02	8.12E+02	8.12E+00	
1.89E+01	5.38E+01	1.71E+02	1.71E+00	
1.01E+03	9.51E+02	2.30E+03	2.30E+01	
1.86E+02	5.53E+02	1.36E+03	1.36E+01	
8.93E-01	8.37E-01	2.14E+00	2.14E-02	
1.51E-03	4.48E-03	1.93E-02	1.93E-04	
3.23E-02	2.91E-02	8.06E-02	8.06E-04	
5.98E-02	5.62E-02	1.51E-01	1.51E-03	
1.67E+00	1.57E+00	4.15E+00	4.15E-02	
3.89E+01	7.70E+00	1.30E+02	1.30E+00	
1.09E+01	1.05E+01	3.65E+01	3.65E-01	
1.01E+02	1.34E+02	4.24E+02	4.24E+00	
1.04E+03	1.00E+03	3.45E+03	3.45E+01	
1.09E+00	4.93E-02	2.11E+00	2.11E-02	
4.84E+05	2.21E+06	3.09E+06	3.09E+04	
4.84E+05	2.21E+06	3.09E+06	3.09E+04	
4.10E+01	3.78E+01	1.17E+02	1.17E+00	
5.03E+01	4.57E+01	1.42E+02	1.42E+00	
1.61E+02	9.37E+01	4.13E+02	4.13E+00	

EIS TR input	EIS AE input	AE/TR ratio	AE			
			5.21E+02			
			1.10E+00			
			1.37E+01			
			8.41E+01			
7.870E+01	5.330E+01	6.773E-01	5.33E+01			
			1.56E+01			
			1.55E+02			
4.270E-01	2.900E-01	6.792E-01	2.90E-01			
			6.93E+01			
			1.58E+00			
			8.23E+00			
			4.21E+03			
			1.95E+01			
			1.60E+03			
7.630E+03	5.180E+03	6.789E-01	3.01E+03			
1.260E+01	8.560E+00	6.794E-01	8.56E+00			
			8.55E+01			
			2.04E+01			
			4.37E+02			
			7.96E-01			
			1.70E+03			
			1.57E+02			
1.480E+01	1.000E+01	6.757E-01	1.00E+01			
			3.25E+00			
4.810E-03	3.26E-03	6.777E-01				
6.440E-01	4.29E-01	6.666E-01				
7.830E-03	5.31E-03	6.781E-01				

3.640E-02	2.47E-02	6.786E-01				
1.300E+00	6.03E-01	4.636E-01				
4.130E+00	2.80E+00	6.779E-01				

RPP-CALC-60497, Rev. 0

EIS AX AE NO3 source term				NO3 rate	NO3 source term	NO2 rate	NO2 source term	NO3 Mass Check		NO2 Mass Check	
3.47E+09	s	1.87E-07	1/s	1.09E-07	3.471336E+09,s, 1.090574E-07,1/s,	5.80E-08	3.471336E+09,s, 5.801998E-08,1/s,				
3.50E+09	s	1.87E-07	1/s	1.09E-07	3.502894E+09,s, 1.090574E-07,1/s,	5.80E-08	3.502894E+09,s, 5.801998E-08,1/s,	344.163		183.099	
3.50E+09	s	1.66E-07	1/s	9.66E-08	3.502894E+09,s, 9.661620E-08,1/s,	5.14E-08	3.502894E+09,s, 5.140108E-08,1/s,				
3.53E+09	s	1.66E-07	1/s	9.66E-08	3.534451E+09,s, 9.661620E-08,1/s,	5.14E-08	3.534451E+09,s, 5.140108E-08,1/s,	304.892		162.206	
3.53E+09	s	1.47E-07	1/s	8.56E-08	3.534451E+09,s, 8.559427E-08,1/s,	4.55E-08	3.534451E+09,s, 4.553727E-08,1/s,				
3.57E+09	s	1.47E-07	1/s	8.56E-08	3.566009E+09,s, 8.559427E-08,1/s,	4.55E-08	3.566009E+09,s, 4.553727E-08,1/s,	270.118		143.707	
3.57E+09	s	1.23E-07	1/s	7.15E-08	3.566009E+09,s, 7.150443E-08,1/s,	3.80E-08	3.566009E+09,s, 3.804129E-08,1/s,				
3.63E+09	s	1.23E-07	1/s	7.15E-08	3.629124E+09,s, 7.150443E-08,1/s,	3.80E-08	3.629124E+09,s, 3.804129E-08,1/s,	451.300		240.098	
3.63E+09	s	9.64E-08	1/s	5.61E-08	3.629124E+09,s, 5.612059E-08,1/s,	2.99E-08	3.629124E+09,s, 2.985689E-08,1/s,				
3.69E+09	s	9.64E-08	1/s	5.61E-08	3.692239E+09,s, 5.612059E-08,1/s,	2.99E-08	3.692239E+09,s, 2.985689E-08,1/s,	354.205		188.442	
3.69E+09	s	7.56E-08	1/s	4.40E-08	3.692239E+09,s, 4.404653E-08,1/s,	2.34E-08	3.692239E+09,s, 2.343333E-08,1/s,				
3.76E+09	s	7.56E-08	1/s	4.40E-08	3.755354E+09,s, 4.404653E-08,1/s,	2.34E-08	3.755354E+09,s, 2.343333E-08,1/s,	278.000		147.899	
3.76E+09	s	5.60E-08	1/s	3.26E-08	3.755354E+09,s, 3.263802E-08,1/s,	1.74E-08	3.755354E+09,s, 1.736385E-08,1/s,				
3.85E+09	s	5.60E-08	1/s	3.26E-08	3.850027E+09,s, 3.263802E-08,1/s,	1.74E-08	3.850027E+09,s, 1.736385E-08,1/s,	308.994		164.389	
3.85E+09	s	3.68E-08	1/s	2.15E-08	3.850027E+09,s, 2.145152E-08,1/s,	1.14E-08	3.850027E+09,s, 1.141249E-08,1/s,				
3.98E+09	s	3.68E-08	1/s	2.15E-08	3.976258E+09,s, 2.145152E-08,1/s,	1.14E-08	3.976258E+09,s, 1.141249E-08,1/s,	270.785		144.061	
3.98E+09	s	1.83E-08	1/s	1.07E-08	3.976258E+09,s, 1.067696E-08,1/s,	5.68E-09	3.976258E+09,s, 5.680281E-09,1/s,				
4.23E+09	s	1.83E-08	1/s	1.07E-08	4.228718E+09,s, 1.067696E-08,1/s,	5.68E-09	4.228718E+09,s, 5.680281E-09,1/s,	269.551		143.404	
4.23E+09	s	2.59E-09	1/s	1.51E-09	4.228718E+09,s, 1.511183E-09,1/s,	8.04E-10	4.228718E+09,s, 8.039689E-10,1/s,				
5.30E+09	s	2.59E-09	1/s	1.51E-09	5.301677E+09,s, 1.511183E-09,1/s,	8.04E-10	5.301677E+09,s, 8.039689E-10,1/s,	162.144		86.263	
5.30E+09	s	0.00E+00	1/s	0.00E+00	5.301677E+09,s, 0.000000E+00,1/s,	0.00E+00	5.301677E+09,s, 0.000000E+00,1/s,				
3.16E+11	s	0.00E+00	1/s	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.000		0.000	
								3014.2	3014.7	1603.6	1603.9

istart	istop	inodes
17	26	10
jstart	jstop	jnodes
17	26	10

RPP-CALC-60497, Rev. 0

EIS AX TR		NO3 source term		NO3 rate	NO3 source term	NO2 rate	NO2 source term	NO3 Mass Check		NO2 Mass Check	
3.47E+09	s	2.05E-07	1/s	1.20E-07	3.471336E+09,s, 1.195480E-07,1/s,	6.36E-08	3.471336E+09,s, 6.360111E-08,1/s,				
3.50E+09	s	2.05E-07	1/s	1.20E-07	3.502894E+09,s, 1.195480E-07,1/s,	6.36E-08	3.502894E+09,s, 6.360111E-08,1/s,	377.270		200.712	
3.50E+09	s	1.80E-07	1/s	1.05E-07	3.502894E+09,s, 1.047547E-07,1/s,	5.57E-08	3.502894E+09,s, 5.573084E-08,1/s,				
3.57E+09	s	1.80E-07	1/s	1.05E-07	3.566009E+09,s, 1.047547E-07,1/s,	5.57E-08	3.566009E+09,s, 5.573084E-08,1/s,	661.159		351.745	
3.57E+09	s	1.51E-07	1/s	8.77E-08	3.566009E+09,s, 8.772265E-08,1/s,	4.67E-08	3.566009E+09,s, 4.666960E-08,1/s,				
3.63E+09	s	1.51E-07	1/s	8.77E-08	3.629124E+09,s, 8.772265E-08,1/s,	4.67E-08	3.629124E+09,s, 4.666960E-08,1/s,	553.662		294.555	
3.63E+09	s	1.26E-07	1/s	7.35E-08	3.629124E+09,s, 7.345990E-08,1/s,	3.91E-08	3.629124E+09,s, 3.908163E-08,1/s,				
3.69E+09	s	1.26E-07	1/s	7.35E-08	3.692239E+09,s, 7.345990E-08,1/s,	3.91E-08	3.692239E+09,s, 3.908163E-08,1/s,	463.642		246.664	
3.69E+09	s	1.01E-07	1/s	5.89E-08	3.692239E+09,s, 5.894340E-08,1/s,	3.14E-08	3.692239E+09,s, 3.135866E-08,1/s,				
3.79E+09	s	1.01E-07	1/s	5.89E-08	3.786912E+09,s, 5.894340E-08,1/s,	3.14E-08	3.786912E+09,s, 3.135866E-08,1/s,	558.035		296.882	
3.79E+09	s	7.76E-08	1/s	4.52E-08	3.786912E+09,s, 4.516925E-08,1/s,	2.40E-08	3.786912E+09,s, 2.403063E-08,1/s,				
3.88E+09	s	7.76E-08	1/s	4.52E-08	3.881585E+09,s, 4.516925E-08,1/s,	2.40E-08	3.881585E+09,s, 2.403063E-08,1/s,	427.631		227.505	
3.88E+09	s	5.70E-08	1/s	3.32E-08	3.881585E+09,s, 3.318797E-08,1/s,	1.77E-08	3.881585E+09,s, 1.765643E-08,1/s,				
4.01E+09	s	5.70E-08	1/s	3.32E-08	4.007815E+09,s, 3.318797E-08,1/s,	1.77E-08	4.007815E+09,s, 1.765643E-08,1/s,	418.932		222.877	
4.01E+09	s	3.54E-08	1/s	2.06E-08	4.007815E+09,s, 2.059407E-08,1/s,	1.10E-08	4.007815E+09,s, 1.095631E-08,1/s,				
4.23E+09	s	3.54E-08	1/s	2.06E-08	4.228718E+09,s, 2.059407E-08,1/s,	1.10E-08	4.228718E+09,s, 1.095631E-08,1/s,	454.929		242.028	
4.23E+09	s	1.32E-08	1/s	7.67E-09	4.228718E+09,s, 7.670556E-09,1/s,	4.08E-09	4.228718E+09,s, 4.080836E-09,1/s,				
4.77E+09	s	1.32E-08	1/s	7.67E-09	4.765198E+09,s, 7.670556E-09,1/s,	4.08E-09	4.765198E+09,s, 4.080836E-09,1/s,	411.510		218.929	
4.77E+09	s	1.66E-09	1/s	9.64E-10	4.765198E+09,s, 9.639791E-10,1/s,	5.13E-10	4.765198E+09,s, 5.128495E-10,1/s,				
5.93E+09	s	1.66E-09	1/s	9.64E-10	5.932829E+09,s, 9.639791E-10,1/s,	5.13E-10	5.932829E+09,s, 5.128495E-10,1/s,	112.557		59.882	
5.93E+09	s	0.00E+00	1/s	0.00E+00	5.932829E+09,s, 0.000000E+00,1/s,	0.00E+00	5.932829E+09,s, 0.000000E+00,1/s,				
3.16E+11	s	0.00E+00	1/s	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.000		0.000	
								4439.3	4446.0	2361.8	2365.3

istart	istop	inodes
17	26	10

jstart	jstop	jnodes
17	26	10

EIS AX-102 PL NO3 source term	NO3 source term	NO2 source term
1.08E-08 1/s	6.305893E-09 1/s	3.354817E-09 1/s
EIS AX-104 PL NO3 source term		
2.89E-08 1/s	1.681726E-08 1/s	8.947001E-09 1/s

Tank Farm A PL Inventory (kg as NO3) from EIS Table D-27
2.00E+01

Tank Farm A PL Inventory (kg as NO3) as sum from EIS input rates
2.005E+01

RPP-CALC-60497, Rev. 0

EIS A AE NO3 source term			NO3 rate	NO3 source term	NO2 rate	NO2 source term	NO3 Mass Check		NO2 Mass Check	
3.471336E+09 s	1.773476E-07	1/s	9.61E-08	3.471336E+09,s, 9.613735E-08,1/s,	6.03E-08	3.471336E+09,s, 6.025521E-08,1/s,				
3.502894E+09 s	1.773476E-07	1/s	9.61E-08	3.502894E+09,s, 9.613735E-08,1/s,	6.03E-08	3.502894E+09,s, 6.025521E-08,1/s,	485.424		304.245	
3.502894E+09 s	1.544645E-07	1/s	8.37E-08	3.502894E+09,s, 8.373278E-08,1/s,	5.25E-08	3.502894E+09,s, 5.248050E-08,1/s,				
3.534451E+09 s	1.544645E-07	1/s	8.37E-08	3.534451E+09,s, 8.373278E-08,1/s,	5.25E-08	3.534451E+09,s, 5.248050E-08,1/s,	422.777		264.980	
3.534451E+09 s	1.345340E-07	1/s	7.29E-08	3.534451E+09,s, 7.292877E-08,1/s,	4.57E-08	3.534451E+09,s, 4.570896E-08,1/s,				
3.566009E+09 s	1.345340E-07	1/s	7.29E-08	3.566009E+09,s, 7.292877E-08,1/s,	4.57E-08	3.566009E+09,s, 4.570896E-08,1/s,	368.238		230.797	
3.566009E+09 s	1.096156E-07	1/s	5.94E-08	3.566009E+09,s, 5.942090E-08,1/s,	3.72E-08	3.566009E+09,s, 3.724274E-08,1/s,				
3.629124E+09 s	1.096156E-07	1/s	5.94E-08	3.629124E+09,s, 5.942090E-08,1/s,	3.72E-08	3.629124E+09,s, 3.724274E-08,1/s,	600.056		376.092	
3.629124E+09 s	8.315318E-08	1/s	4.51E-08	3.629124E+09,s, 4.507603E-08,1/s,	2.83E-08	3.629124E+09,s, 2.825193E-08,1/s,				
3.692239E+09 s	8.315318E-08	1/s	4.51E-08	3.692239E+09,s, 4.507603E-08,1/s,	2.83E-08	3.692239E+09,s, 2.825193E-08,1/s,	455.196		285.299	
3.692239E+09 s	6.307910E-08	1/s	3.42E-08	3.692239E+09,s, 3.419419E-08,1/s,	2.14E-08	3.692239E+09,s, 2.143161E-08,1/s,				
3.755354E+09 s	6.307910E-08	1/s	3.42E-08	3.755354E+09,s, 3.419419E-08,1/s,	2.14E-08	3.755354E+09,s, 2.143161E-08,1/s,	345.307		216.425	
3.755354E+09 s	4.483498E-08	1/s	2.43E-08	3.755354E+09,s, 2.430434E-08,1/s,	1.52E-08	3.755354E+09,s, 1.523303E-08,1/s,				
3.850027E+09 s	4.483498E-08	1/s	2.43E-08	3.850027E+09,s, 2.430434E-08,1/s,	1.52E-08	3.850027E+09,s, 1.523303E-08,1/s,	368.154		230.745	
3.850027E+09 s	2.612921E-08	1/s	1.42E-08	3.850027E+09,s, 1.416423E-08,1/s,	8.88E-09	3.850027E+09,s, 8.877600E-09,1/s,				
4.007815E+09 s	2.612921E-08	1/s	1.42E-08	4.007815E+09,s, 1.416423E-08,1/s,	8.88E-09	4.007815E+09,s, 8.877600E-09,1/s,	357.591		224.125	
4.007815E+09 s	6.686515E-09	1/s	3.62E-09	4.007815E+09,s, 3.624655E-09,1/s,	2.27E-09	4.007815E+09,s, 2.271795E-09,1/s,				
4.575852E+09 s	6.686515E-09	1/s	3.62E-09	4.575852E+09,s, 3.624655E-09,1/s,	2.27E-09	4.575852E+09,s, 2.271795E-09,1/s,	329.430		206.474	
4.575852E+09 s	6.076969E-10	1/s	3.29E-10	4.575852E+09,s, 3.294229E-10,1/s,	2.06E-10	4.575852E+09,s, 2.064697E-10,1/s,				
5.080774E+09 s	6.076969E-10	1/s	3.29E-10	5.080774E+09,s, 3.294229E-10,1/s,	2.06E-10	5.080774E+09,s, 2.064697E-10,1/s,	26.613		16.680	
5.080774E+09 s	0.000000E+00	1/s	0.00E+00	5.080774E+09,s, 0.000000E+00,1/s,	0.00E+00	5.080774E+09,s, 0.000000E+00,1/s,				
3.155760E+11 s	0.000000E+00	1/s	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.000		0.000	
							3758.8	3764.0	2355.9	2359.2

istart	istop	inodes
17	32	16
jstart	jstop	jnodes
17	26	10

RPP-CALC-60497, Rev. 0

EIS A TR NO3 source term			NO3 rate	NO3 source term	NO2 rate	NO2 source term	NO3 Mass Check		NO2 Mass Check	
3.471336E+09 s	1.739898E-07	1/s	9.43E-08	3.471336E+09,s, 9.431714E-08,1/s,	5.91E-08	3.471336E+09,s, 5.911437E-08,1/s,				
3.502894E+09 s	1.739898E-07	1/s	9.43E-08	3.502894E+09,s, 9.431714E-08,1/s,	5.91E-08	3.502894E+09,s, 5.911437E-08,1/s,	476.234		298.485	
3.502894E+09 s	1.580667E-07	1/s	8.57E-08	3.502894E+09,s, 8.568548E-08,1/s,	5.37E-08	3.502894E+09,s, 5.370437E-08,1/s,				
3.566009E+09 s	1.580667E-07	1/s	8.57E-08	3.566009E+09,s, 8.568548E-08,1/s,	5.37E-08	3.566009E+09,s, 5.370437E-08,1/s,	865.286		542.328	
3.566009E+09 s	1.389833E-07	1/s	7.53E-08	3.566009E+09,s, 7.534066E-08,1/s,	4.72E-08	3.566009E+09,s, 4.722064E-08,1/s,				
3.629124E+09 s	1.389833E-07	1/s	7.53E-08	3.629124E+09,s, 7.534066E-08,1/s,	4.72E-08	3.629124E+09,s, 4.722064E-08,1/s,	760.820		476.853	
3.629124E+09 s	1.184377E-07	1/s	6.42E-08	3.629124E+09,s, 6.420322E-08,1/s,	4.02E-08	3.629124E+09,s, 4.024012E-08,1/s,				
3.723797E+09 s	1.184377E-07	1/s	6.42E-08	3.723797E+09,s, 6.420322E-08,1/s,	4.02E-08	3.723797E+09,s, 4.024012E-08,1/s,	972.530		609.544	
3.723797E+09 s	9.765033E-08	1/s	5.29E-08	3.723797E+09,s, 5.293471E-08,1/s,	3.32E-08	3.723797E+09,s, 3.317745E-08,1/s,				
3.818470E+09 s	9.765033E-08	1/s	5.29E-08	3.818470E+09,s, 5.293471E-08,1/s,	3.32E-08	3.818470E+09,s, 3.317745E-08,1/s,	801.838		502.561	
3.818470E+09 s	7.805698E-08	1/s	4.23E-08	3.818470E+09,s, 4.231346E-08,1/s,	2.65E-08	3.818470E+09,s, 2.652046E-08,1/s,				
3.944700E+09 s	7.805698E-08	1/s	4.23E-08	3.944700E+09,s, 4.231346E-08,1/s,	2.65E-08	3.944700E+09,s, 2.652046E-08,1/s,	854.597		535.628	
3.944700E+09 s	5.852754E-08	1/s	3.17E-08	3.944700E+09,s, 3.172686E-08,1/s,	1.99E-08	3.944700E+09,s, 1.988518E-08,1/s,				
4.102488E+09 s	5.852754E-08	1/s	3.17E-08	4.102488E+09,s, 3.172686E-08,1/s,	1.99E-08	4.102488E+09,s, 1.988518E-08,1/s,	800.979		502.023	
4.102488E+09 s	3.995032E-08	1/s	2.17E-08	4.102488E+09,s, 2.165644E-08,1/s,	1.36E-08	4.102488E+09,s, 1.357343E-08,1/s,				
4.323391E+09 s	3.995032E-08	1/s	2.17E-08	4.323391E+09,s, 2.165644E-08,1/s,	1.36E-08	4.323391E+09,s, 1.357343E-08,1/s,	765.436		479.746	
4.323391E+09 s	2.203786E-08	1/s	1.19E-08	4.323391E+09,s, 1.194638E-08,1/s,	7.49E-09	4.323391E+09,s, 7.487532E-09,1/s,				
4.702082E+09 s	2.203786E-08	1/s	1.19E-08	4.702082E+09,s, 1.194638E-08,1/s,	7.49E-09	4.702082E+09,s, 7.487532E-09,1/s,	723.838		453.674	
4.702082E+09 s	3.253675E-09	1/s	1.76E-09	4.702082E+09,s, 1.763766E-09,1/s,	1.11E-09	4.702082E+09,s, 1.105461E-09,1/s,				
6.879557E+09 s	3.253675E-09	1/s	1.76E-09	6.879557E+09,s, 1.763766E-09,1/s,	1.11E-09	6.879557E+09,s, 1.105461E-09,1/s,	614.489		385.138	
6.879557E+09 s	0.000000E+00	1/s	0.00E+00	6.879557E+09,s, 0.000000E+00,1/s,	0.00E+00	6.879557E+09,s, 0.000000E+00,1/s,				
3.155760E+11 s	0.000000E+00	1/s	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.00E+00	3.155760E+11,s, 0.000000E+00,1/s,	0.000		0.000	
							7636.0	7653.1	4786.0	4796.7

istart	istop	inodes
17	32	16
jstart	jstop	jnodes
17	26	10

EIS A Farm RL NO3 source term
1.09522E-06 1/s

NO3 source term
5.937016E-07 1/s

NO2 source term
3.721094E-07 1/s

Tank Farm A RL Inventory (kg as NO3) from EIS Table D-33
5.530E+03

Tank Farm A PL Inventory (kg as NO3) as sum from EIS input rates
5.530E+03

istart		istop	inodes	
	17	32		16
jstart		jstop	jnodes	
	17	26		10

	NO3 source term	NO2 source term
EIS A-103 PL NO3 source term		
1.98447E-08 1/s	1.075748E-08 1/s	6.742376E-09 1/s
EIS A-104 PL NO3 source term		
7.13774E-06 1/s	2.735557E-07 1/s	3.268895E-07 1/s
EIS A-105 PL NO3 source term		
2.95095E-06 1/s	6.638708E-08 1/s	1.697034E-07 1/s

Tank Farm A PL Inventory (kg as NO3) from EIS Table D-27
5.190E+02

Tank Farm A PL Inventory (kg as NO3) as sum from EIS input rates
5.104E+03

A-103 Inventory (kg as NO3)
1.002E+01

NO3 inventory (Wood 2003)	NO2 inventory (Wood 2003)	Combined rate (kg as NO3/s)
1.381242E+02 kg	1.650535E+02 kg	7.141279E-07
NO3 inventory (SIM 2005)	NO2 inventory (SIM 2005)	Combined rate (kg as NO3/s)
33.52027 kg	85.68691 kg	2.951085E-07

A-104 Inventory (kg as NO3)
3.606E+02

A-105 Inventory (kg as NO3)
1.490E+02

Tank Farm A Inventory (kg as NO3)
5.196E+02

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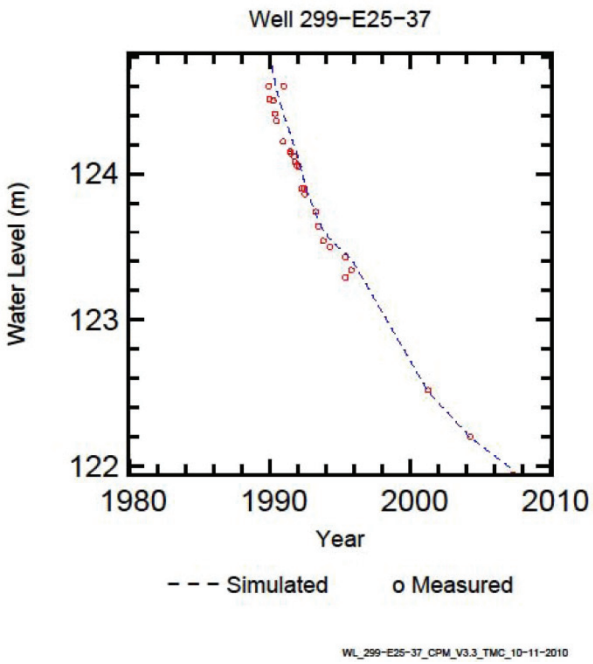
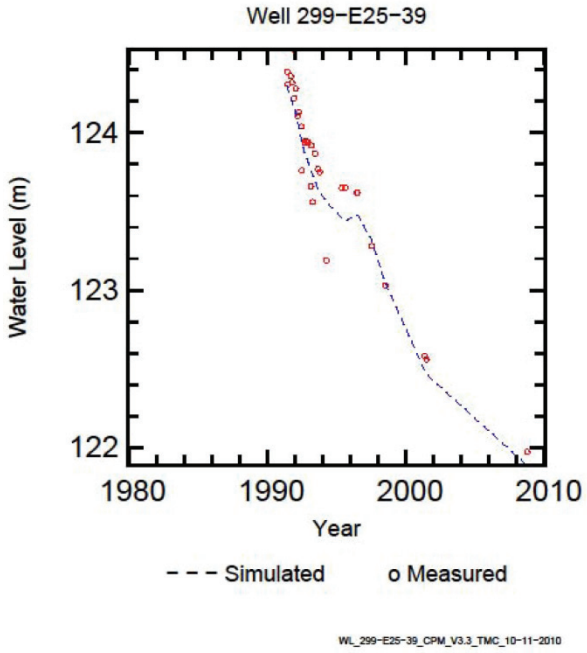
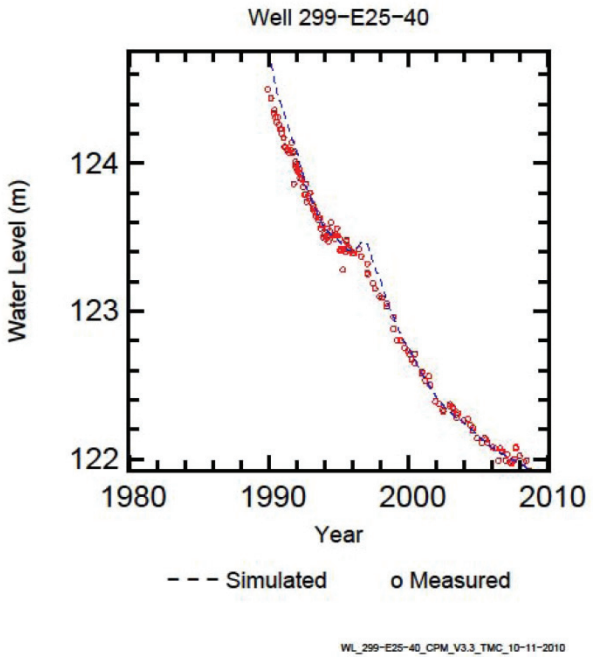
ATTACHMENT 3

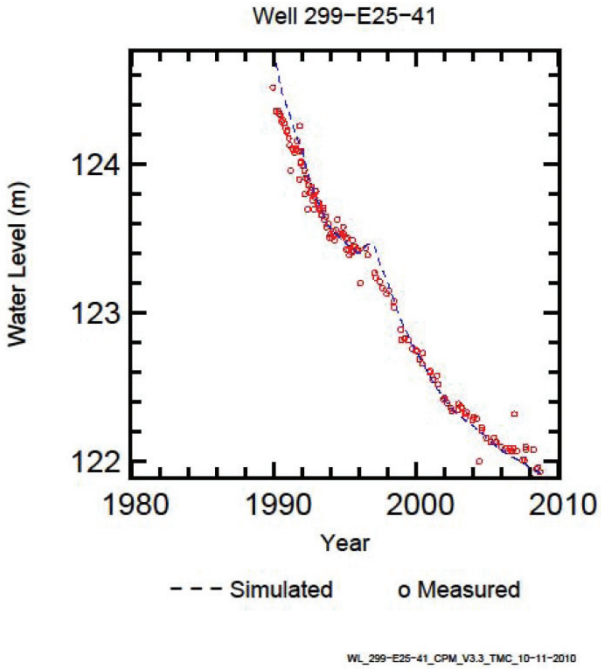
MATERIALS SUPPORTING ASSUMPTIONS AND INPUTS

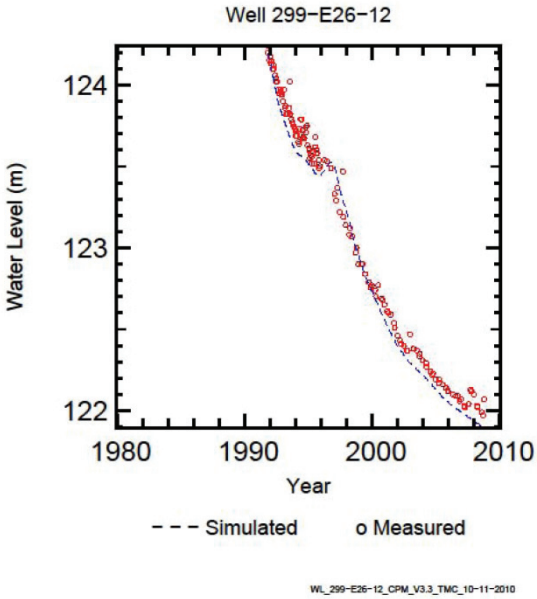
Selected pages from CP-47631, 2014, "Model Package Report, Central Plateau Groundwater Model, Version 6.3.3," Rev. 2, INTERA, Inc., Richland, Washington.

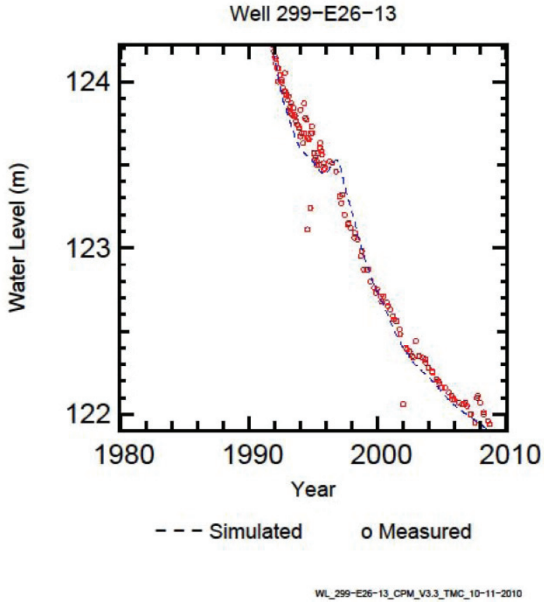

Well 299-E25-37
Water Level (m)
124
123
122
1980
1990
2000
2010
Year
- - - Simulated
o Measured
WL_299-E25-37_CPM_V3.3_TMC_10-11-2010

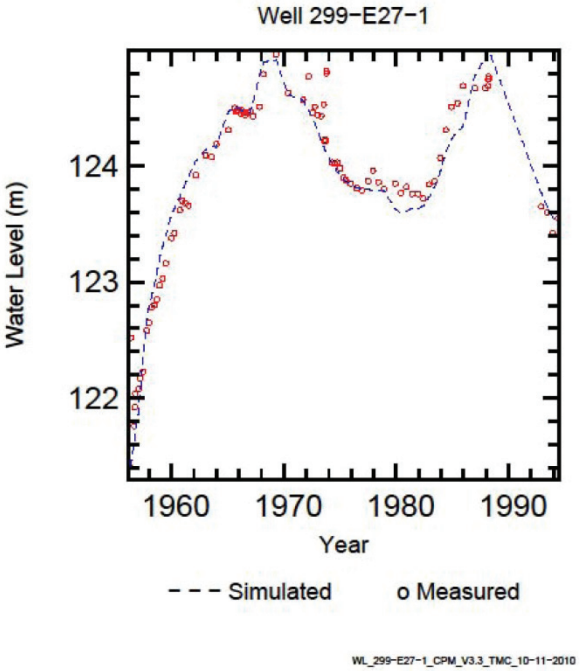

Well 299-E25-39
Water Level (m)
124
123
122
1980
1990
2000
2010
Year
- - - Simulated
o Measured
WL_299-E25-39_CPM_V3.3_TMC_10-11-2010

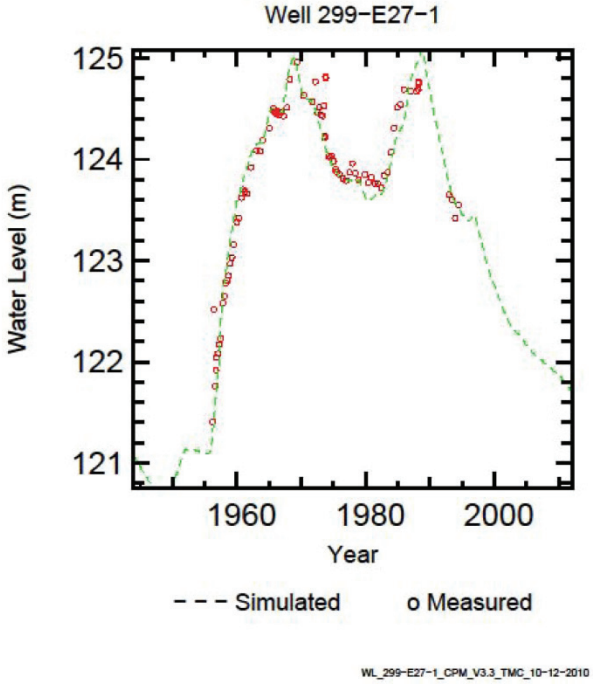

Well 299-E25-40
Water Level (m)
124
123
122
1980
1990
2000
2010
Year
- - - Simulated
o Measured
WL_299-E25-40_CPM_V3.3_TMC_10-11-2010


Well 299-E25-41
Water Level (m)
124
123
122
1980
1990
2000
2010
Year
- - - Simulated
o Measured
WL_299-E25-41_CPM_V3.3_TMC_10-11-2010


Well 299-E26-12
Water Level (m)
124
123
122
1980
1990
2000
2010
Year
Simulated
o Measured
WL_299-E26-12_CPM_V3.3_TMC_10-11-2010


Well 299-E26-13
Water Level (m)
124
123
122
1980
1990
2000
2010
Year
Simulated
o Measured
WL_299-E26-13_CPM_V3.3_TMC_10-11-2010


Well 299-E27-1
Water Level (m)
124
123
122
1960
1970
1980
1990
Year
Simulated
o Measured
WL_299-E27-1_CPM_V3.3_TMC_10-11-2010


Well 299-E27-1
Water Level (m)
125
124
123
122
121
1960
1980
2000
Year
Simulated
o Measured
WL_299-E27-1_CPM_V3.3_TMC_10-12-2010

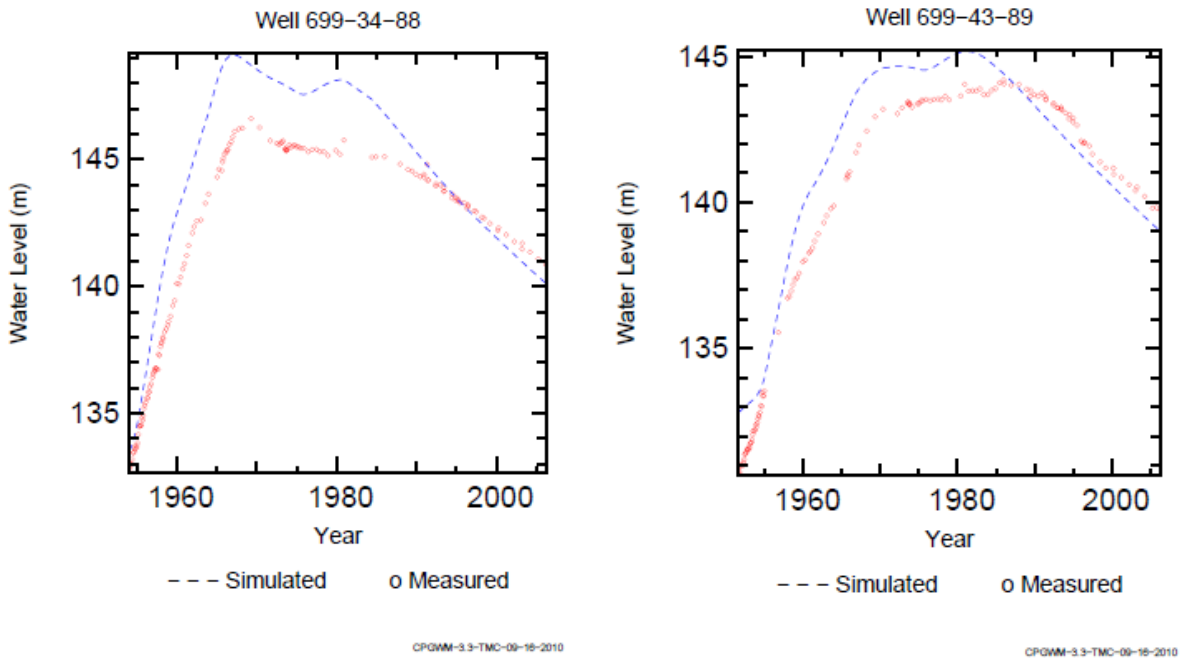


Figure 4-40 (Cont'd). Selected Measured and Simulated Hydrographs Version 3.3 Calibration

Table 4-9 presents a synopsis of the calibrated input parameters used in the CPGW Model Version 3.3. Figure 4-29 identifies the well locations. Hydrographs are presented east-to-west. In general, the fits in the 200 East Area are very good. Nearer to the southeast boundary, the fit is very good until the water level declines of the late 1990s and beyond. Fits just west of the Hanford channels can be quite poor (well 699-40-62 and well 699-32-62). More refinement of the extent of the HSU may improve the model here. It is believed that the delay and lateral transport of fluid due to perching is an important factor contribution to poor matches near the 200 West Area. The fact that the CPGW Model, which simulates saturated groundwater flow, does not represent this feature of the recharge process can be considered a source of structural weakness in the mode; however, the significance of this structural weakness is not altogether clear since it depends on the intended use of the model. Regardless, as described earlier in the discussion of observation weights for model calibration, it would be an error to force the model to reproduce the hydrographs here accurately without introducing a perching sub model. The fits in the northwest portion of the model domain are amenable to improvement with further effort.

Table 4-9. Central Plateau Groundwater Model Calibration Results

Parameter	Units	CPGW Model Version		
		2.0	3.0	3.3*
Coarse Grained Hanford Hydraulic Conductivity	m/day (horizontal)	8,500	10,000	17,000
	m/day (vertical)	850	1,000	1,200
Fine Grained Hanford Hydraulic Conductivity	m/day (horizontal)	NA	100.0	40
	m/day (vertical)	NA	10.0	5

Table 4-9. Central Plateau Groundwater Model Calibration Results

Parameter	Units	CPGW Model Version		
		2.0	3.0	3.3*
Cold Creek Hydraulic Conductivity	m/day (horizontal)	100	106	400
	m/day (vertical)	10	10.6	20
Ringold E Hydraulic Conductivity	m/day (horizontal)	5	5	5
	m/day (vertical)	0.5	0.5	0.5
Ringold A Hydraulic Conductivity	m/day (horizontal)	3.5	4.8	4.8
	m/day (vertical)	0.35	0.48	0.48
Ringold Mud Hydraulic Conductivity	m/day (horizontal)	0.3	0.008	0.008
	m/day (vertical)	0.03	0.0008	0.0008
Hanford and Cold Creek Specific Yield - SY1	m/m	0.15	0.1	0.2
Ringold E, mud and Ringold A - SY2	m/m	0.18	0.0905	0.0905
Hanford and Cold Creek Specific Storage -SS1	1/m	0.00001	0.00001	0.00001
Ringold E, mud and Ringold A - SS2	1/m	0.00001	0.00001	0.00001
Cold Creek Flow	m^3/day	5,722	2,500	2,500
Dry Creek Flow	m^3/day	1,231	700	700
East GHB Hanford Multiplier	Unitless	0.1	0.25	0.25
East GHB Cold Creek Multiplier	Unitless	0.1	0.06	0.06
East GHB Ringold E and A Multiplier	Unitless	0.1	0.06	0.06
South GHB Hanford formation Multiplier	Unitless	0.1	0.25	0.3
South GHB Cold Creek unit Multiplier	Unitless	0.1	0.06	0.3
South GHB Ringold E and A units Multiplier	Unitless	0.1	0.05	0.3
South GHB Scale Factor	Unitless	0.3	0.1	1
East GHB North Factor	Unitless	1	0.035	0.03
East GHB Central Factor	Unitless	NA	0.28	0.2
East GHB South Factor	Unitless	0.5	0.38	0.14
Division between North East and Central East	Unitless	Row 90	Row 90	Row 90
Division between Central East and South East	Unitless	NA	Row 120	Row 110

NA = not applicable

* Version 3.4 retains the calibration developed for Version 3.3, with minor refinements to HSU assignments and boundary conditions noted in Sections 4.2.5.2, 4.2.6.1, and 4.4.1.1.

Selected pages from Periodic Table of Elements from CRC Handbook of Chemistry and Physics

PERIODIC TABLE OF THE ELEMENTS

New Notation → 1, 2, 13, 14, 15, 16, 17, 18
Previous IUPAC Form → Group IA, IIA, IIIB, IVB, VB, VIB, VIIB, VIII, IB, IIB, IIIB, IVA, VA, VIA, VIIA, VIIIA
CAS Version → IA, IIA, IIIA, IVA, VA, VIA, VIIA, VIII, IB, IIB, IIIB, IVB, VB, VIB, VIIB, VIII, IB, IIB, IIIA, IVA, VA, VIA, VIIA, VIIIA

Key to Chart
Atomic Number → 50
Symbol → Sn
2001 Atomic Weight → 118.710
Oxidation States → +2 +4
Electron Configuration → -18-18-4

Group IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA	Shell
1 +1 -1 H 1.00794 1																	2 0 He 4.002602 2	K
3 +1 Li 6.941 2-1	4 +2 Be 9.012182 2-2											5 +3 B 10.811 2-3	6 +2 +4 -4 C 12.0107 2-4	7 +1 +2 +3 +4 +5 -1 -2 -3 N 14.0067 2-5	8 -2 O 15.9994 2-6	9 -1 F 18.9984032 2-7	10 0 Ne 20.1797 2-8	K-L
11 +1 Na 22.989770 2-8-1	12 +2 Mg 24.3050 2-8-2											13 +3 Al 26.981538 2-8-3	14 +2 +4 -4 Si 28.0855 2-8-4	15 +3 +5 -3 P 30.973761 2-8-5	16 +4 +6 -2 S 32.065 2-8-6	17 +1 +5 +7 -1 Cl 35.453 2-8-7	18 0 Ar 39.948 2-8-8	K-L-M
19 +1 K 39.0983 -8-8-1	20 +2 Ca 40.078 -8-8-2	21 +3 Sc 44.955910 -8-9-2	22 +2 +3 +4 Ti 47.867 -8-10-2	23 +2 +3 +4 +5 V 50.9415 -8-11-2	24 +2 +3 +6 Cr 51.9961 -8-13-1	25 +2 +3 +4 +7 Mn 54.938049 -8-13-2	26 +2 +3 Fe 55.845 -8-14-2	27 +2 +3 Co 58.933200 -8-15-2	28 +2 +3 Ni 58.6934 -8-16-2	29 +1 +2 Cu 63.546 -8-18-1	30 +2 Zn 65.409 -8-18-2	31 +3 Ga 69.723 -8-18-3	32 +2 +4 Ge 72.64 -8-18-4	33 +3 +5 -3 As 74.92160 -8-18-5	34 +4 +6 -2 Se 78.96 -8-18-6	35 +1 +5 -1 Br 79.904 -8-18-7	36 0 Kr 83.798 -8-18-8	-L-M-N
37 +1 Rb 85.4678 -18-8-1	38 +2 Sr 87.62 -18-8-2	39 +3 Y 88.90585 -18-9-2	40 +4 Zr 91.224 -18-10-2	41 +3 +5 Nb 92.90638 -18-12-1	42 +6 Mo 95.94 -18-13-1	43 +4 +6 +7 Tc (98) -18-13-2	44 +3 Ru 101.07 -18-15-1	45 +3 Rh 102.90550 -18-16-1	46 +2 +3 Pd 106.42 -18-18-0	47 +1 Ag 107.8682 -18-18-1	48 +2 Cd 112.411 -18-18-2	49 +3 In 114.818 -18-18-3	50 +2 +4 Sn 118.710 -18-18 -4	51 +3 +5 -3 Sb 121.760 -18-18-5	52 +4 +6 -2 Te 127.60 -18-18-6	53 +1 +5 +7 -1 I 126.90447 -18-18-7	54 0 Xe 131.293 -18-18-8	-M-N-O
55 +1 Cs 132.90545 -18-8-1	56 +2 Ba 137.327 -18-8-2	57* +3 La 138.9055 -18-9-2	72 +4 Hf 178.49 -32-10-2	73 +5 Ta 180.9479 -32-11-2	74 +6 W 183.84 -32-12-2	75 +4 +6 +7 Re 186.207 -32-13-2	76 +3 +4 Os 190.23 -32-14-2	77 +3 +4 Ir 192.217 -32-15-2	78 +2 +4 Pt 195.078 -32-17-1	79 +1 +3 Au 196.96655 -32-18-1	80 +1 +2 Hg 200.59 -32-18-2	81 +1 +3 Tl 204.3833 -32-18-3	82 +2 +4 Pb 207.2 -32-18-4	83 +3 +5 Bi 208.98038 -32-18-5	84 +2 +4 Po (209) -32-18-6	85 At (210) -32-18-7	86 0 Rn (222) -32-18-8	-N-O-P
87 +1 Fr (223) -18-8-1	88 +2 Ra (226) -18-8-2	89** +3 Ac (227) -18-9-2	104 +4 Rf (261) -32-10-2	105 Db (262) -32-11-2	106 Sg (266) -32-12-2	107 Bh (272) -32-13-2	108 Hs (277) -32-14-2	109 Mt (276) -32-15-2	110 Ds (281) -32-16-2	111 Rg (280)	112 Cn (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (292)		118 Uuo (294)	-O-P-Q

* Lanthanides	58 +3 +4 Ce 140.116 -19-9-2	59 +3 Pr 140.90765 -21-8-2	60 +3 Nd 144.24 -22-8-2	61 +3 Pm (145) -23-8-2	62 +2 +3 Sm 150.36 -24-8-2	63 +2 +3 Eu 151.964 -25-8-2	64 +3 Gd 157 .25 -25-9-2	65 +3 Tb 158.92534 -27-8-2	66 +3 Dy 162.500 -28-8-2	67 +3 Ho 164.93032 -29-8-2	68 +3 Er 167.259 -30-8-2	69 +3 Tm 168.93421 -31-8-2	70 +2 +3 Yb 173.04 -32-8-2	71 +3 Lu 174.967 -32-9-2		-N-O-P
** Actinides	90 +4 Th 232.0381 -18-10-2	91 +5 +4 Pa 231.03588 -20-9-2	92 +3 +4 +5 +6 U 238.02891 -21-9-2	93 +3 +4 +5 +6 Np (237) -22-9-2	94 +3 +4 +5 +6 Pu (244) -24-8-2	95 +3 +4 +5 +6 Am (243) -25-8-2	96 +3 Cm (247) -25-9-2	97 +3 +4 Bk (247) -27-8-2	98 +3 Cf (251) -28-8-2	99 +3 Es (252) -29-8-2	100 +3 Fm (257) -30-8-2	101 +2 +3 Md (258) -31-8-2	102 +2 +3 No (259) -32-8-2	103 +3 Lr (262) -32-8-3		-O-P-Q

The new IUPAC format numbers the groups from 1 to 18. The previous IUPAC numbering system and the system used by Chemical Abstracts Service (CAS) are also shown. For radioactive elements that do not occur in nature, the mass number of the most stable isotope is given in parentheses. Elements 113–116 and 118 have been reported but not yet confirmed.

References

1. G. J. Leigh, Editor, *Nomenclature of Inorganic Chemistry*, Blackwell Scientific Publications, Oxford, 1990.
2. *Chemical and Engineering News*, 63(5), 27, 1985.
3. Atomic Weights of the Elements, 2007, *Pure & Appl. Chem.*, 81, 2131, 2009.

- Metallic solids
- Non-metallic solids
- Liquids
- Gases

Selected pages from Appendix Q of DOE/EIS-0391, 2012, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington, United States Department of Energy, Richland, Washington

related equipment. These releases would involve both radioactive and chemical constituents. Because a large number of constituents, sources, and scenarios have been considered, screening analysis was used to identify a reduced number of controlling scenarios. The results of this human health impacts analysis for onsite, offsite, and intruder receptors are summarized in the following sections.

Q.3.1.1 Impacts on Onsite and Offsite Receptors of Expected Conditions Under Tank Closure Alternatives

Implementation of activities defined for the Tank Closure alternatives could lead to releases of radioactive and chemical constituents to the environment over long periods of time. In the case of Tank Closure Alternatives 1 and 2A, these releases would not be controlled by engineered closure of the tanks, while under the other Tank Closure alternatives, releases would be controlled by stabilization of the tanks and of wastes generated during retrieval and closure activities. Potential human health impacts due to release of radioactive constituents are estimated as dose and as lifetime risk of incidence of cancer. Potential human health effects due to release of chemical constituents include both carcinogenic effects and other forms of toxicity. Impacts of carcinogenic chemicals are estimated as lifetime risk of incidence of cancer. Noncarcinogenic effects are estimated as Hazard Quotient, the ratio of the long-term intake of a single chemical to the highest intake that produces no observable effect, and as Hazard Index, the sum of the Hazard Quotients of the group of chemicals contributing to impacts through the exposure pathways evaluated in a particular scenario. Further information on the nature of human health effects in response to exposure to radioactive and chemical constituents is provided in Appendix K, Section K.1. As previously discussed in Section Q.2 of this appendix, the screening analysis identified 14 radioactive and 26 chemical constituents as contributing the greatest risk of adverse impacts. Impacts due to exposure to these constituents are presented in this appendix.

The four measures of human health impacts considered in this analysis—lifetime risks of developing cancer from radioactive and chemical constituents, dose from radioactive constituents, and Hazard Index from chemical constituents—were calculated for each year from CYs 1940 through 11,939 (i.e., 10,000 years) for each receptor at eight locations (i.e., A, B, S, T and U Barriers; Core Zone Boundary; Columbia River nearshore; and Columbia River surface water). This is a large amount of information that must be summarized to allow interpretation of results. The method chosen is to present dose for the year of maximum dose, risk for the year of maximum risk, and Hazard Index for the year of maximum Hazard Index. This choice is based on regulation of radiological impacts expressed as dose and the observation that peak risk and peak noncarcinogenic impacts expressed as Hazard Index may occur at times other than that of peak dose. The significance of dose impacts is evaluated by comparison against the 100-millirem-per-year all-exposure-modes standard specified for protection of the public and the environment in DOE Order 458.1. Population doses are compared against a total effective dose equivalent from natural background sources of 311 millirem per year for a member of the population of the United States (NCRP 2009). The significance of noncarcinogenic chemical impacts is evaluated by comparison against a guideline value of unity (1) for Hazard Index. The level of protection provided for the drinking water pathway is evaluated by comparison against the maximum contaminant levels (MCLs) of the "National Primary Drinking Water Regulations" (40 CFR 141) and other benchmarks presented in Appendix O. In addition, only those radioactive and chemical constituents that resulted in a lifetime risk or Hazard Index greater than 1×10^{-10} for all impacts analysis locations for a given source are included in the human health impact tables presented in this section to reduce the size of the tables. Although a regulatory standard for risk has not been proposed for tank closure impacts, perspective on magnitude of estimated risks may be gained by comparison against the Hanford site-specific cleanup goal of 1×10^{-5}. Also, to provide a basis for understanding the evolution of impacts over time, graphs are presented to depict the lifetime radiological risk for the drinking-water well user at the Core Zone Boundary due to releases from individual sources and due to releases from the combined sources. In interpreting these figures, note that the graph of time series of risk for the combined sources may overlay or obscure the time series of risk for a single dominant source.

Impacts related to tank farm operations, retrieval and closure are due to three types of release. The first type of release is the past practice of direct discharge of liquid to cribs and trenches (ditches). The second type of release is due to past activity at the tank farms and includes past leaks from damaged tanks. The third type of release is due to future activities and includes leaks during retrieval of waste from the tanks, and long-term leaching of waste material in tanks and ancillary equipment. The combination of unplanned releases from past events and retrieval leaks and releases from tank residuals on ancillary equipment in the future is referred to as "other tank farm sources" in subsequent text.

The balance of this section summarizes the potential human health effects due to implementation of each Tank Closure alternative. Seven onsite locations at which an individual may contact groundwater and an offsite location were selected for analysis. The seven onsite locations are the boundaries of tank farm barriers, the Core Zone Boundary, and the Columbia River nearshore. The offsite location is an access point to Columbia River surface water, which could be at various points near the site and at population centers downstream of the site. Total offsite population is 5 million people.

Consistent with DOE guidance (DOE Guide 435.1-1), the potential consequences of loss of administrative or institutional control are considered by estimation of impacts on onsite receptors. Because DOE does not anticipate loss of control of the site, these onsite receptors are considered hypothetical and are applied to develop estimates for past and future periods of time.

Four types of receptors are considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses either groundwater or surface water, but not both, for drinking water consumption and irrigation of crops. Garden size and crop yield are adequate to produce approximately 25 percent of average requirements of crops and animal products. The third type, an American Indian resident farmer, also uses either groundwater or surface water, but not both, for drinking water consumption and irrigation of crops. Garden size and crop yield are adequate to produce the entirety of average requirements of crops and animal products. The fourth type, an American Indian hunter-gatherer, is impacted by both groundwater and surface water because he uses surface water for drinking water consumption and consumes wild plant materials, which use groundwater, and game, which use surface water. In subsequent subsections, estimates of impacts are presented in two sets of tables, one set for receptors using groundwater and one set for users of surface water. To facilitate presentation, estimates of impact on the American Indian hunter-gatherer are presented in the set of tables for surface-water users. Members of the offsite populations are assumed to have the activity pattern of a residential farmer, using surface water to meet the total annual drinking water requirement and to irrigate a garden that provides approximately 25 percent of annual crop and animal product requirements. These receptors are also assumed to consume fish harvested from the river. Impacts on an individual of the offsite population are the same as those reported in tables in this appendix for the resident farmer at the Columbia River surface-water location.

Impacts that depend upon or would be affected by Tank Closure alternatives would be evident after CY 2050, the approximate time assumed for placement of engineered caps. However, releases to the vadose zone associated with past practices such as planned discharges to cribs and trenches (ditches) and with leaks from tanks occurring after CY 1940 but before CY 2050, may continue to produce impacts into the future. Because of uncertainties in estimates of the time of occurrence of impacts and the perspective that could be added by knowledge of past impacts, estimates of peak impacts are provided for time periods beginning in CY 1940 and in CY 2050. In addition, a time series of estimates of radiological risk for the drinking-water well user at the Core Zone Boundary is presented to provide a view of the evolution of impacts over the entire period of analysis. Further discussion about these receptors is provided in Section Q.2 of this appendix.

The results of the analysis for drinking-water well users after CY 2050 are summarized in Tables Q–18 through Q–21 for radioactive and chemical constituents. Impacts due to ingestion of

drinking water under Tank Closure Alternative 1, which assumes catastrophic failure of the tanks, would approach but not exceed the 100-millirem-per-year dose standard at the A Barrier. For the other Tank Closure alternatives, the results indicate that planned discharges to cribs and trenches (ditches) and past leaks at the B, BX, BY, T, and TX tank farms would be important contributors to radiological and chemical impacts (see subsequent text for detailed results). Under Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, 4, 5, 6A (Base and Option Cases), 6B (Base and Option Cases), and 6C, doses would not be greater than the 100-millirem-per-year standard at any location. Under all Tank Closure alternatives, doses estimated for drinking water ingestion are less than 10 millirem per year at the Columbia River nearshore location. For impacts occurring prior to CY 5000, radiological impacts would be due to tritium, technetium-99 and iodine-129; chemical impacts would be due to chromium and nitrate. For impacts occurring after CY 5000, radiological impacts would be due to uranium isotopes; chemical impacts would be due to total uranium.

Table Q–18. Summary of Radiation Dose at Year of Peak Dose for the Drinking-Water Well User (millirem per year)

	Tank Closure Alternative								
Location	**1**	**2A**	**2B, 3A, 3B, 3C, 6C**	**4**	**5**	**6A, Base Case**	**6A, Option Case**	**6B, Base Case**	**6B, Option Case**
A Barrier	8.37×10^{1} (2121)	2.17 (2095)	1.74 (2102)	1.78 (2100)	2.00 (4155)	2.16 (2103)	2.16 (2103)	1.99 (2093)	1.99 (2093)
B Barrier	5.88×10^{1} (4313)	8.64 (2069)	7.55 (2056)	7.38 (2056)	7.54 (2056)	7.34 (2056)	7.64 (2066)	7.32 (2056)	7.92 (2065)
S Barrier	4.73×10^{1} (3072)	3.50 (2051)	3.43 (2051)	4.54×10^{-1} (2050)	6.15 (4321)	3.36 (2052)	3.36 (2052)	3.42 (2050)	3.42 (2050)
T Barrier	1.52×10^{1} (2051)	1.51×10^{1} (2050)	1.55×10^{1} (2050)	1.55×10^{1} (2050)	1.56×10^{1} (2050)	1.54×10^{1} (2050)	1.53×10^{1} (2050)	1.52×10^{1} (2050)	1.51×10^{1} (2051)
U Barrier	2.23×10^{1} (4002)	1.14 (2100)	5.20×10^{-1} (3296)	3.14×10^{-1} (2058)	2.58 (3949)	2.89×10^{-1} (2067)	2.89×10^{-1} (2067)	2.86×10^{-1} (2067)	2.86×10^{-1} (2067)
Core Zone Boundary	5.88×10^{1} (4313)	8.64 (2069)	7.58 (2056)	7.41 (2056)	7.57 (2056)	7.37 (2056)	7.64 (2066)	7.35 (2056)	7.92 (2065)
Columbia River nearshore	4.37 (4978)	9.41×10^{-1} (2317)	8.85×10^{-1} (2242)	8.82×10^{-1} (2242)	8.94×10^{-1} (4809)	8.76×10^{-1} (2251)	8.99×10^{-1} (2251)	8.22×10^{-1} (2218)	8.07×10^{-1} (2218)

Note: Dose for year of peak dose, with calendar year of peak dose in parentheses.

Table Q–69. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Human Health Impacts Related to Past Leaks at the A Barrier Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	**Dose at Year of Peak Dose (millirem per year)**	**Radiological Risk at Year of Peak Radiological Risk**	**Concentration at Year of Peak Dose (curies per cubic meter)**	**Dose at Year of Peak Dose (millirem per year)**	**Radiological Risk at Year of Peak Radiological Risk**	**Concentration at Year of Peak Dose (curies per cubic meter)**	**Dose at Year of Peak Dose (millirem per year)**	**Radiological Risk at Year of Peak Radiological Risk**
Hydrogen-3 (tritium)	1.90×10^{-7}	2.23×10^{-2}	2.11×10^{-7}	1.90×10^{-7}	2.59×10^{-2}	2.55×10^{-7}	1.90×10^{-7}	3.08×10^{-2}	3.23×10^{-7}
Technetium-99	1.40×10^{-6}	2.44	8.40×10^{-5}	1.40×10^{-6}	6.30	2.76×10^{-4}	1.40×10^{-6}	1.29×10^{1}	6.04×10^{-4}
Iodine-129	5.45×10^{-10}	1.55×10^{-1}	1.76×10^{-6}	5.45×10^{-10}	1.94×10^{-1}	2.73×10^{-6}	5.45×10^{-10}	2.51×10^{-1}	4.13×10^{-6}
Total	**N/A**	**2.62**	**8.60×10^{-5}**	**N/A**	**6.52**	**2.79×10^{-4}**	**N/A**	**1.31×10^{1}**	**6.09×10^{-4}**
Year of peak impact	2004	2004	2004	2004	2004	2004	2004	2004	2004
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Chromium	6.58×10^{-2}	6.26×10^{-1}	0.00	6.58×10^{-2}	6.49×10^{-1}	2.58×10^{-10}	6.58×10^{-2}	9.77×10^{-1}	1.18×10^{-5}
Nitrate	2.13	3.81×10^{-2}	0.00	2.13	2.99×10^{-1}	0.00	2.13	6.67×10^{-1}	0.00
Total	**N/A**	**6.64×10^{-1}**	**0.00**	**N/A**	**9.49×10^{-1}**	**2.58×10^{-10}**	**N/A**	**1.64**	**1.18×10^{-5}**
Year of peak impact	2104	2104	N/A	2104	2104	2104	2104	2104	2104

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable.

Table Q–92. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Human Health Impacts Related to Retrieval Leaks at the A Barrier Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Hydrogen-3 (tritium)	1.63×10^{-9}	1.91×10^{-4}	1.81×10^{-9}	1.63×10^{-9}	2.22×10^{-4}	2.18×10^{-9}	1.63×10^{-9}	2.64×10^{-4}	2.77×10^{-9}
Technetium-99	9.44×10^{-8}	1.65×10^{-1}	5.68×10^{-6}	9.44×10^{-8}	4.26×10^{-1}	1.87×10^{-5}	9.44×10^{-8}	8.70×10^{-1}	4.09×10^{-5}
Iodine-129	1.62×10^{-10}	4.62×10^{-2}	5.26×10^{-7}	1.62×10^{-10}	5.77×10^{-2}	8.13×10^{-7}	1.62×10^{-10}	7.46×10^{-2}	1.23×10^{-6}
Total	**N/A**	**2.12×10^{-1}**	**6.21×10^{-6}**	**N/A**	**4.84×10^{-1}**	**1.95×10^{-5}**	**N/A**	**9.45×10^{-1}**	**4.21×10^{-5}**
Year of peak impact	2063	2063	2063	2063	2063	2063	2063	2063	2063
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Chromium	1.35×10^{-3}	1.28×10^{-2}	0.00	1.35×10^{-3}	1.33×10^{-2}	1.27×10^{-11}	1.35×10^{-3}	2.00×10^{-2}	5.82×10^{-7}
Nitrate	3.19	5.69×10^{-2}	0.00	3.19	4.47×10^{-1}	0.00	3.19	9.98×10^{-1}	0.00
Total	**N/A**	**6.97×10^{-2}**	**0.00**	**N/A**	**4.61×10^{-1}**	**1.27×10^{-11}**	**N/A**	**1.02**	**5.82×10^{-7}**
Year of peak impact	2062	2062	N/A	2062	2062	2163	2062	2062	2163

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable.

Table Q–100. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Human Health Impacts Related to Releases from Ancillary Equipment at the A Barrier Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Technetium-99	3.11×10^{-8}	5.43×10^{-2}	1.87×10^{-6}	3.11×10^{-8}	1.40×10^{-1}	6.15×10^{-6}	3.11×10^{-8}	2.86×10^{-1}	1.34×10^{-5}
Iodine-129	3.68×10^{-11}	1.05×10^{-2}	1.19×10^{-7}	3.68×10^{-11}	1.31×10^{-2}	1.84×10^{-7}	3.68×10^{-11}	1.69×10^{-2}	2.79×10^{-7}
Total	**N/A**	**6.48×10^{-2}**	**1.99×10^{-6}**	**N/A**	**1.53×10^{-1}**	**6.33×10^{-6}**	**N/A**	**3.03×10^{-1}**	**1.37×10^{-5}**
Year of peak impact	3610	3610	3610	3610	3610	3610	3610	3610	3610
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Acetonitrile	8.09×10^{-6}	3.85×10^{-5}	0.00	9.35×10^{-6}	5.56×10^{-5}	0.00	9.35×10^{-6}	1.01×10^{-4}	0.00
Chromium	1.30×10^{-3}	1.24×10^{-2}	0.00	1.25×10^{-3}	1.23×10^{-2}	5.12×10^{-12}	1.25×10^{-3}	1.85×10^{-2}	2.35×10^{-7}
Nitrate	1.67×10^{-1}	2.97×10^{-3}	0.00	1.83×10^{-1}	2.56×10^{-2}	0.00	1.83×10^{-1}	5.71×10^{-2}	0.00
Total	**N/A**	**1.54×10^{-2}**	**0.00**	**N/A**	**3.80×10^{-2}**	**5.12×10^{-12}**	**N/A**	**7.58×10^{-2}**	**2.35×10^{-7}**
Year of peak impact	3647	3647	N/A	3648	3648	3647	3648	3648	3647

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable.

Table Q–108. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Human Health Impacts Related to Releases from Tank Residuals at the A Barrier Boundary

Radioactive Constituent	Drinking-Water Well User			Resident Farmer			American Indian Resident Farmer		
	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk	Concentration at Year of Peak Dose (curies per cubic meter)	Dose at Year of Peak Dose (millirem per year)	Radiological Risk at Year of Peak Radiological Risk
Technetium-99	1.60×10^{-7}	2.79×10^{-1}	9.60×10^{-6}	1.60×10^{-7}	7.19×10^{-1}	3.16×10^{-5}	1.60×10^{-7}	1.47	6.91×10^{-5}
Iodine-129	7.02×10^{-11}	2.00×10^{-2}	2.28×10^{-7}	7.02×10^{-11}	2.50×10^{-2}	3.52×10^{-7}	7.02×10^{-11}	3.23×10^{-2}	5.32×10^{-7}
Total	**N/A**	**2.99×10^{-1}**	**9.83×10^{-6}**	**N/A**	**7.44×10^{-1}**	**3.19×10^{-5}**	**N/A**	**1.50**	**6.96×10^{-5}**
Year of peak impact	3685	3685	3685	3685	3685	3685	3685	3685	3685
Chemical Constituent	**Drinking-Water Well User**			**Resident Farmer**			**American Indian Resident Farmer**		
	Concentration at Year of Peak Hazard Index (grams per cubic meter)	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**	**Concentration at Year of Peak Hazard Index (grams per cubic meter)**	**Hazard Index at Year of Peak Hazard Index**	**Nonradiological Risk at Year of Peak Nonradiological Risk**
Acetonitrile	2.43×10^{-4}	1.15×10^{-3}	0.00	3.24×10^{-4}	1.93×10^{-3}	0.00	1.76×10^{-4}	1.89×10^{-3}	0.00
Chromium	5.42×10^{-3}	5.16×10^{-2}	0.00	4.67×10^{-3}	4.61×10^{-2}	2.13×10^{-11}	4.33×10^{-3}	6.43×10^{-2}	9.77×10^{-7}
Nitrate	4.17×10^{-1}	7.44×10^{-3}	0.00	4.95×10^{-1}	6.95×10^{-2}	0.00	5.23×10^{-1}	1.64×10^{-1}	0.00
Total	**N/A**	**6.02×10^{-2}**	**0.00**	**N/A**	**1.18×10^{-1}**	**2.13×10^{-11}**	**N/A**	**2.30×10^{-1}**	**9.77×10^{-7}**
Year of peak impact	3451	3451	N/A	3573	3573	3451	3443	3443	3451

Note: Concentrations are those reported for groundwater at the specified location. Total concentrations, although reported, are not used in the analysis.
Key: N/A=not applicable.

Selected pages from Appendix L of DOE/EIS-0391, 2012, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington, United States Department of Energy, Richland, Washington

Table L–15. 95th Percentile (Base Case) Flow Model Calibrated Hydraulic Conductivity Values

Material Type (Model Zone)	Hydraulic Conductivity (K_x)[a]	Hydraulic Conductivity (K_y)[b]	Hydraulic Conductivity (K_z)[c]
Hanford mud (1)	0.171	0.171	0.0171
Hanford silt (2)	6.8	6.8	0.68
Hanford sand (3)	123.6	123.6	12.36
Hanford gravel (4)	156.0	156.0	15.6
Ringold sand (5)	3.57	3.57	0.357
Ringold gravel (6)	19.2	19.2	1.92
Ringold mud (7)	1.514	1.514	0.1514
Ringold silt (8)	1.51	1.51	0.151
Plio-Pleistocene sand (9)	96.8	96.8	9.68
Plio-Pleistocene silt (10)	5.81	5.81	0.581
Cold Creek sand (11)	99.13	99.13	9.913
Cold Creek gravel (12)	62.7	62.7	6.27
Highly conductive Hanford formation (13)	3982.0	3982.0	398.2
Activated basalt (14)	0.001	0.001	0.0001

[a] Hydraulic conductivity with respect to the *x* axis, meters per day.
[b] Hydraulic conductivity with respect to the *y* axis, meters per day.
[c] Hydraulic conductivity with respect to the *z* axis, meters per day.
Note: To convert meters to feet, multiply by 3.281.

Table L–16. Flow Model Hydraulic Conductivity Parameter Correlation Coefficient Matrix

Model Zone	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.00	–0.01	0.00	0.02	–0.02	0.00	0.00	0.02	0.00	0.04	0.00	0.01	0.01
2	–0.01	1.00	0.02	0.03	–0.03	0.01	–0.01	0.00	–0.03	0.02	–0.02	–0.01	–0.02
3	0.00	0.02	1.00	–0.03	0.02	0.00	0.02	–0.02	–0.02	0.01	0.01	–0.02	–0.02
4	0.02	0.03	–0.03	1.00	0.00	–0.03	–0.01	0.00	0.02	0.02	–0.01	–0.02	0.02
5	–0.02	–0.03	0.02	0.00	1.00	–0.02	0.01	–0.01	0.00	0.02	–0.02	0.00	–0.01
6	0.00	0.01	0.00	–0.03	–0.02	1.00	–0.03	–0.01	–0.01	0.01	0.03	–0.02	0.00
7	0.00	–0.01	0.02	–0.01	0.01	–0.03	1.00	0.00	0.00	0.00	0.01	0.00	–0.03
8	0.02	0.00	–0.02	0.00	–0.01	–0.01	0.00	1.00	–0.01	0.01	0.01	0.01	–0.01
9	0.00	–0.03	–0.02	0.02	0.00	–0.01	0.00	–0.01	1.00	0.02	0.01	0.00	–0.03
10	0.04	0.02	0.01	0.02	0.02	0.01	0.00	0.01	0.02	1.00	0.02	0.00	–0.03
11	0.00	–0.02	0.01	–0.01	–0.02	0.03	0.01	0.01	0.01	0.02	1.00	0.02	–0.02
12	0.01	–0.01	–0.02	–0.02	0.00	–0.02	0.00	0.01	0.00	0.00	0.02	1.00	0.01
13	0.01	–0.02	–0.02	0.02	–0.01	0.00	–0.03	–0.01	–0.03	–0.03	–0.02	0.01	1.00

Selected pages from Appendix N of DOE/EIS-0391, 2012, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington, United States Department of Energy, Richland, Washington

N.3.6.2 Constituent Properties

Values of distribution coefficients for radionuclides in the vadose zone vary with the geochemistry of the liquid phase and the texture of the soil phase and have been measured for some (Cantrell, Serne, and Last 2003) but not all radionuclides considered in this *TC & WM EIS*. To represent all required constituents and maintain consistency with other site analysis, the following hierarchy of sources was followed:

1. Technical guidance for this *TC & WM EIS* (DOE 2005)
2. Results for sand from of a survey of distribution-coefficient data from sites across the Nation (Sheppard and Thibault 1990)
3. Frequency distributions of the values of distribution coefficients recommended for near-surface soils from regulatory guidance (Beyeler et al. 1999)

The single set of the values of distribution coefficients for radionuclides is summarized in Table N–2.

Table N–2. Values of Distribution Coefficients for Radionuclides

Radionuclide	Distribution Coefficient (milliliters per gram)	Source
Hydrogen-3 (tritium)	0	DOE 2005
Carbon	4	DOE 2005
Potassium	1.5×10^{1}	Sheppard and Thibault 1990
Strontium	1×10^{1}	DOE 2005
Zirconium	6×10^{2}	Sheppard and Thibault 1990
Technetium	0	DOE 2005
Iodine	0	DOE 2005
Cesium	8×10^{1}	DOE 2005
Gadolinium	5	Beyeler et al. 1999
Thorium	3.2×10^{3}	Sheppard and Thibault 1990
Uranium	0.6	DOE 2005
Neptunium	2.5	DOE 2005
Plutonium	1.5×10^{2}	DOE 2005
Americium	1.9×10^{3}	Sheppard and Thibault 1990

Estimates for distribution coefficients are required for inorganic and organic chemical constituents. For inorganic chemical constituents, the hierarchy of sources described above for radionuclides was followed. For organic chemical constituents, estimates of the values of the distribution coefficients were developed based on project guidance (DOE 2005) and regulatory guidance (EPA 1996). The set of values for the distribution coefficients for organic and inorganic chemical constituents is summarized in Table N–3.

Table N–3. Values of Distribution Coefficients for Organic Chemical Constituents

Chemical	Distribution Coefficient (milliliters per gram)	Source
Arsenic	4×10^{2}	Beyeler et al. 1999
Boron	0	N/A
Cadmium	8×10^{1}	Sheppard and Thibault 1990
Chromium	0	DOE 2005
Fluoride	0	N/A
Lead	8×10^{1}	DOE 2005
Manganese	5×10^{1}	Sheppard and Thibault 1990
Mercury	1×10^{1}	DOE 2005
Molybdenum	1×10^{1}	Sheppard and Thibault 1990
Nickel	4×10^{2}	Sheppard and Thibault 1990
Nitrate	0	DOE 2005
Silver	9×10^{1}	Sheppard and Thibault 1990
Strontium	1×10^{1}	DOE 2005
Uranium	6×10^{-1}	DOE 2005
Acetonitrile	0	DOE 2005
Benzene	1	DOE 2005
Butanol (n-butyl-alcohol)	3	DOE 2005
Polychlorinated biphenyls	1.7×10^{5}	DOE 2005
2,4,6-Trichlorophenol	3.8×10^{-1}	DOE 2005
1,2-Dichloroethane[a]	0	EPA 1996
1,4-Dioxane[a]	0	EPA 1996
Carbon tetrachloride[a]	0	EPA 1996
Dichloromethane[a]	0	EPA 1996
Hydrazine[a]	0	EPA 1996
Vinyl chloride[a]	0	EPA 1996
Trichloroethylene[a]	0	EPA 1996

a Values calculated based on reported values of organic carbon partition coefficients (EPA 1996) and Hanford soil organic content of 0.02 percent (Riley et al. 2005; Wellman et al. 2007).

Key: N/A=not applicable.

N.3.6.3 Transport Properties

Soils comprising the vadose zone at Hanford include a variety of material types and a range of physical structures characterized by anisotropic properties and heterogeneity over a range of distance scales. These anisotropic and heterogeneous conditions produce a spatial spreading of concentration of solute moving through the vadose zone, even if the aqueous flow underlying the transport is uniform over time and distance scales that are large with respect to the scales of transport of the solute. This spreading occurs both parallel and transverse to the direction of pore-water velocity flow and is characterized by the dispersivity parameter. Although theoretical prediction of values of dispersivity has been investigated (Gelhar and Axness 1983), the primary source of estimates of dispersivity is fitting solute transport model parameters to field data. The approach adopted for selection of values of dispersivity for *TC & WM EIS* analysis is review of literature reports, selection of recommended values of longitudinal (in direction of

Selected pages from DOE/ORP-2005-01, 2006, Initial Single-Shell Tank System Performance Assessment for the Hanford Site, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

Table 3-6. Nonreactive Macrodispersivity Estimates for Various Strata at Waste Management Areas C and S-SX

Strata	σ^2_{LnK}	Correlation length, λ cm	A_L cm	A_T cm
Backfill	4.54	30	~150	15
Sandy H2	4.60	30	~150	15
Gravelly Sand H3	4.95	30	~150	15
Gravelly Sand H1	3.19	30	~100	10
Plio-Pleistocene Sandy Silt	0.92	30	~50	5
Plio-Pleistocene/Ringold Sandy Gravel	4.54	30	~150	15

Heterogeneous Sorption Enhanced Macrodispersivities for the Reactive Species. The net effect of sorption is to retard the velocity at which the contaminant migrates through the porous media. Because sorption for specific contaminants may be a function of soil properties, as the soil properties experience spatial variability, the sorption also varies (Gelhar 1993; Talbott and Gelhar 1994). Stochastic analysis results for macrodispersivity enhancement for various strata in WMA C and S-SX are given in the modeling data package reports (Khaleel et al. 2006a, 2006b).

3.4.4.1.3 Contaminant Distribution Coefficients. Table 3-7 lists the contaminant distribution coefficient (K_d) bins used in this SST PA for various contaminants. Contaminant K_d values are adapted from:

- Section 4.3 of *Vadose Zone Hydrogeology Data Package for the 2004 Composite Analysis* (Last et al. 2004a)
- *Hanford Contaminant Distribution Coefficient Database and Users Guide* (Cantrell et al. 2002, 2003)
- *Soil Screening Guidance: Technical Background Document* (EPA 2000a)
- *Selection of K_d Values for INTEC Groundwater Modeling* (Jenkins 2001)
- *Engineering Design File – Fate and Transport Modeling Results and Summary Report* (INEEL 2004)
- *A Practical Guide to Groundwater and Solute Transport Modeling* (Spitz and Moreno 1996)
- *Risk Assessment Information System* (ORNL 2005).

A number of K_d bins are used to represent the range of sediment-contaminant chemical interaction for the variety of contaminants in various WMAs (Section 3.2.2.4.7).

Table 3-7. Contaminant Distribution Coefficients (mL/g) for Analytes that are Part of the Single-Shell Tank System Inventory (2 pages)

K_d = 0 mL/g			
Tritium	Tantalum	Oxalate	Neodymium
Carbon-14	Tellurium	Phosphate	N-nitroso-di-n-propylamine
Technetium-99	Tungsten	Benzyl alcohol	n-Nitrosomorpholine
Bismuth	Yttrium	Chloroethene	Phenol
Cerium	Acetate	Cyclohexanone	Pyridine
Chloride	Ammonia	Dichloromethane	Tetrahydrofuran
Chromium	Ammonium	Diethyl ether	Vanadium pentoxide
Praseodymium	Fluoride	Ethyl Acetate	2-Butanone(MEK)
Rhodium	Formate	Glycolate	2-Chlorophenol
Rubidium	Hydroxide	Isobutanol	2-Ethoxyethanol
Sodium	Nitrate	Lanthanum	2-Nitropropane
Sulfate	Nitrite	n-Butyl alcohol	2-Propanone
K_d = 0.02 mL/g			
Benzene	Nitrobenzene	1, 1, 1-Trichloroethane	1, 2-Dichloroethane
Carbon disulfide	Toluene	1, 1, 2, 2-Tetrachloroethane	4-Methyl-2-pentanone (MIBK)
Carbon tetrachloride	trans-1, 3-dichloropropene	1, 1, 2-Trichloroethane	
Chloroform	Trichlorofluoromethane	1, 1, 2-Trichloroethylene	
Ethylbenzene	Xylenes	1, 1-Dichloroethene	
K_d = 0.1 mL/g			
Cobalt-60	Cresylic acid	o-Nitrophenol	2, 4, 6-Trichlorophenol
Cobalt	m-Cresol	o-Xylene	2, 4-Dinitrotoluene
Chlorobenzene	o-Dichlorobenzene	Tetrachloroethylene	2-Methylphenol
K_d = 0.2 mL/g			
Iodine-129	Pentachlorophenol	1, 4-Dichlorobenzene	
p-Chloro-m-cresol	1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	2, 4, 5-Trichlorophenol	
K_d = 0.6 mL/g			
Uranium-232	Uranium-235 + D	Uranium	1, 2, 4-Trichlorobenzene
Uranium-233	Uranium-236	Naphthalene	
Uranium-234	Uranium-238 + D	Tributyl phosphate	

Table 3-7. Contaminant Distribution Coefficients (mL/g) for Analytes that are Part of the Single-Shell Tank System Inventory (2 pages)

K_d = 1.0 mL/g			
Ruthenium-106	Europium-152	Aluminum	Ruthenium
Cadmium-113m	Europium-154	Antimony	Thorium
Antimony-125	Europium-155	Cadmium	Tin
Tin-126	Radium-226 + D	Europium	Acenaphthene
Samarium-151	Radium-228 + D	Manganese	Ruthenium
K_d = 2.0 mL/g			
Selenium-79	Neptunium-237 + D	Plutonium-241 + D	Curium-244
Thorium-228 + D	Plutonium-238	Curium-242	Silver
Thorium-229 + D	Plutonium-239	Plutonium-242	Boron
Thorium-230	Plutonium-240	Americium-243 + D	Di-n-butylphthalate
Thorium-232	Americium-241	Curium-243	
K_d = 5.0 mL/g			
Actinium-227 + D	Zirconium-93	Mercury	Zirconium
Cesium-134	Arsenic	Molybdenum	Cyanide
Cesium-137 + daughters	Barium	Nickel	Aroclor-1254
Molybdenum-93	Beryllium	Selenium	Butylbenzylphthalate
Nickel-59	Calcium	Silicon	Di-n-octylphthalate
Nickel-63	Copper	Strontium	Fluoranthene
Niobium-93m	Iron	Thallium	Hexachlorobutadiene
Niobium-94	Lead	Titanium	Hexachloroethane
Protactinium-231	Lithium	Vanadium	Pyrene
Strontium-90 + D	Magnesium	Zinc	

Contaminant K_d values for many of the organic chemicals were estimated using the organic carbon partition coefficients (K_{oc}) method described in *Understanding Variation in Partition Coefficient K_d Values* (EPA 1999), and an estimated fractional organic carbon content for Hanford Site sediments of 0.03% (Cantrell et al. 2003). Contaminants for which inventory estimates exist and that do not have an assigned K_d value are assumed to have a $K_d = 0$. A soil material description of low organic, low salt, with a near-neutral pH is assumed. Appendix D contains a complete listing of contaminants and K_d bins. A brief discussion of each major contaminant follows.

Uranium. Uranium mobility is one of the most difficult features of the analysis to estimate. Significant work on uranium speciation and mobility is documented in Knepp (2002b) and Myers (2005). Last et al. (2004b) recommends the best estimate K_d value for uranium selected

for most Hanford Site impact zones and source categories is 0.8 mL/g, with a range of 0.2 to 4. A reference case of 0.6 mL/g is selected for use in the reference case to represent a balance between possible conditions associated with tank wastes near the source and within the much larger vadose zone away from the source.

Technetium-99 (as Pertechnetate). The best estimates for the K_d values of pertechnetate are zero. The ranges were taken to be from zero to 0.1 mL/g for all source and impact zone categories (except gravel corrected). When comparing this range to values tabulated in Cantrell et al. (2002), the range may appear to be somewhat narrow; however, in most cases when higher K_d values were measured, the K_d values were not significantly greater than the standard deviation. As a result of this and the fact that it is known that pertechnetate is a very weak adsorbate, the narrow range for the K_d values was selected.

Iodine-129 (as Iodide). The value selected for the iodide K_d appropriate for most Hanford Site impact zones and source categories is 0.2 mL/g with a range of 0.1 to 2 mL/g. K_d values are assumed to be the same as those for groundwater.

Chromium. The geochemical behavior of chromium has been reviewed by Rai et al. (1988), Palmer and Wittbrodt (1991), Richard and Bourg (1991), and Palmer and Puls (1994). Ball and Nordstrom (1998) present a critical review of the thermodynamic properties for chromium metal and its aqueous ions, hydrolysis species, oxides, and hydroxides. A complete discussion on chromium geochemistry in the Hanford sediments can be found in Krupka et al. (2004).

Chromium(VI) as chromate (CrO_4^{2-}) is likely to be the dominant chromium species in the Hanford vadose zone and upper unconfined aquifer because its domain of predominance extends over a wide range of pH and Eh conditions that are appropriate for the vadose zone and upper unconfined aquifer. Chromium (III) complexes with dissolved ligands such as fluoride, ammonia, and cyanide (Baes and Mesmer 1976).

Limited studies infer that Cr(III), like other +3 cationic metals, is strongly and specifically absorbed by iron and manganese oxides present in soil (Korte et al. 1976). Cantrell et al. (2003) compiled in a single source, K_d values measured with Hanford sediment for radionuclides and CoCs that have potential human health effects in the vadose zone and groundwater at the Hanford Site. Cantrell et al. (2003, Table 10) list the K_d values determined for Cr(VI) for Hanford sediments; they found only a limited number of studies of Cr(VI) adsorption on Hanford sediments. The measured K_d values for Cr(VI) on Hanford sediments range from 0 to 1, with typical values being zero or close to zero, and based on these results, concluded that adsorption of Cr(VI) is very low to nonexistent under normal Hanford groundwater conditions unless conditions are acidic.

Nitrate and Nitrite. The behavior of nitrogen species, such as nitrate, in aqueous, soil, and geochemical systems has been discussed by Lindsay (1979), Lindsay et al. (1981), Stumm and Morgan (1981), Rai et al. (1987), Hem (1986), and others. A large number of studies have been completed related to the chemical and biological processes that transfer nitrogen between the atmosphere, lithosphere, hydrosphere, and biosphere. Nitrate (NO_3^-) is highly mobile and does not sorb or precipitate in sediment systems.

Nitrate is one of the most widespread contaminants associated with past Hanford Site operations. Nitrate does not readily adsorb on minerals under near-neutral and slightly alkaline pH conditions common in sediment systems, and is typically not included in most databases of K_d. Nitrate and nitrite (NO_2^-) are typically assigned K_d values of 0 mL/g. Cantrell et al. (2003) identified only one study in which nitrate adsorption was measured using Hanford sediments. The limited number of K_d values determined for nitrate from this study are listed in Table 12 of Cantrell et al. (2003). Based on these measurements, Cantrell et al. (2003) concluded that within experimental error, nitrate adsorption under Hanford Site relevant conditions is essentially zero (i.e., $K_d = 0$).

Table 3-8 summarizes the contaminant distribution coefficients used for the reference case and the measured ranges in these values for non-impacted soils.

Table 3-8. Contaminant Distribution Coefficients (mL/g) for Non-Impacted Soils [a, b]

Contaminant	Reference Case	Minimum	Maximum
Uranium	0.6	0.2	4
Iodine-129	0.2	0.1	2
Technetium-99	0	0	0.1
Nitrite	0	0	0
Nitrate	0	0	0
Chromium	0	0	0.3

[a] Refers to far-field modeling domain with ambient conditions, and unaffected by past releases and tank leak chemistry.

[b] Last et al. (2004b)

3.4.4.2 Use of Waste Management Areas C and S-SX Breakthrough Curves for Other Waste Management Areas

Detailed contaminant transport calculations using STOMP have only been performed for WMA C and WMA S-SX. Detailed calculations are planned for the other WMAs and will be incorporated into future revisions of the SST PA. To provide an estimate of the human health impacts anticipated from other WMAs that have not been explicitly modeled, the modeling results from WMA C calculations have been used to scale the estimated impacts for other WMAs in the 200 East Area. Similarly, the modeling results from the WMA S-SX calculations have been used to scale the estimated impacts from other WMAs in the 200 West Area. Section 3.2.2.4.8 provides a description of this approach and discusses the reasons why such an approach can provide reasonable estimates for the impacts for other WMAs.

3.4.5 Unconfined Aquifer

For the integrated, saturated-unsaturated, two-dimensional, cross-sectional model up to the WMA fenceline, the flow parameters needed for unconfined aquifer calculations are saturated hydraulic conductivity, effective porosity, hydraulic gradient, and depth to water table. These parameters for WMAs C and S-SX are given in Table 3-9. Estimates of hydraulic properties shown in Table 3-9 are taken from the work of Wurstner et al. (1995) that was used to

Selected pages from Table D-1 in DOE/ORP-2003-02, 2003, Inventory and Source Term Data Package, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

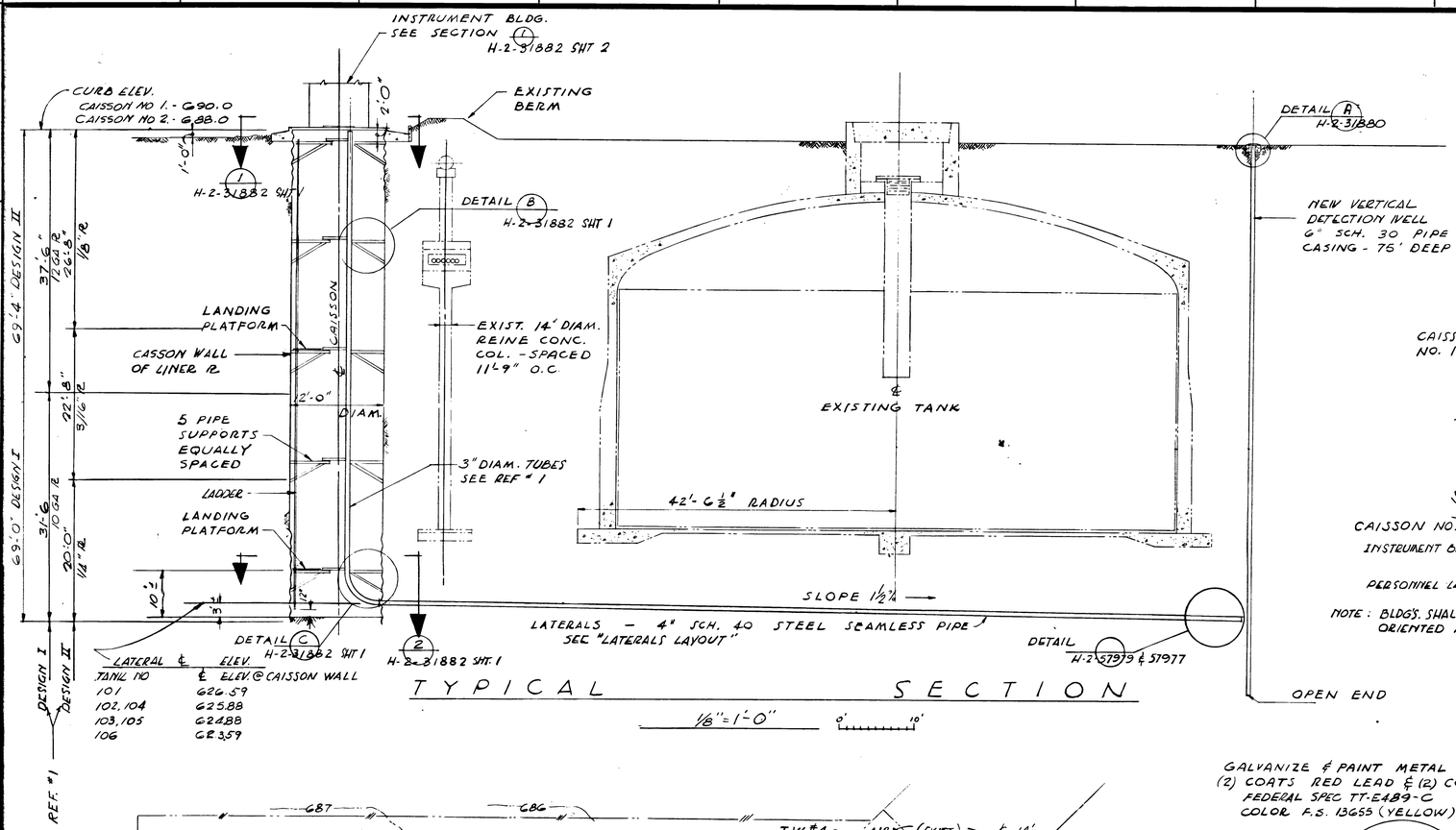
Analyte	Units	A-101	A-102	A-103	A-104	A-105	A-106	AN-101
Al	kg	8.82E+04	7.33E+03	4.43E+04	8.07E+03	8.28E+03	1.47E+04	1.11E+04
Bi	kg	2.63E+02	6.13E+01	1.39E+02	2.06E-01	0.00E+00	1.18E+02	2.66E+01
Ca	kg	9.83E+02	1.23E+02	2.49E+03	1.74E+03	1.95E+03	3.39E+03	1.36E+01
Cl	kg	1.45E+04	1.42E+03	1.01E+04	5.93E+01	7.79E+01	4.05E+03	2.28E+03
Cr	kg	8.54E+03	1.56E+03	2.25E+03	9.01E+01	5.18E+02	3.26E+03	1.09E+02
F	kg	1.40E+03	1.03E+02	2.07E+03	1.35E+00	2.51E+01	1.41E+02	2.28E+02
Fe	kg	1.56E+03	3.47E+03	1.40E+03	2.95E+04	1.92E+04	1.70E+04	6.44E+00
Hg	kg	4.22E+00	0.00E+00	3.74E+00	4.95E+01	6.48E+01	3.69E+01	0.00E+00
K	kg	1.14E+04	7.84E+02	5.42E+03	2.74E+01	7.24E+01	1.45E+03	2.50E+03
La	kg	1.47E+02	1.83E+01	8.80E+01	1.05E+01	3.66E+02	5.24E+01	1.12E+01
Mn	kg	2.36E+02	5.99E+02	1.43E+02	4.13E+03	6.49E+02	9.11E+02	2.66E+00
Na	kg	6.60E+05	3.12E+04	3.78E+05	1.42E+04	5.50E+04	7.85E+04	8.81E+04
Ni	kg	4.19E+02	7.43E+01	2.28E+02	8.98E+02	2.32E+03	4.02E+02	3.70E+00
NO2	kg	2.67E+05	1.48E+04	1.52E+05	3.01E+03	5.57E+02	4.23E+04	4.11E+04
NO3	kg	4.50E+05	2.14E+04	2.29E+05	4.10E+02	1.42E+04	5.03E+04	7.18E+04
Pb	kg	5.02E+02	2.66E+02	2.03E+02	6.74E+01	2.31E+03	6.72E+02	2.62E+01
PO4	kg	1.59E+04	1.11E+03	1.06E+04	4.17E+02	7.94E+03	3.46E+04	1.50E+03
Si	kg	2.29E+03	6.98E+02	1.57E+04	2.47E+03	4.86E+03	2.47E+04	4.29E+01
SO4	kg	6.08E+04	4.87E+03	3.14E+04	8.76E+02	7.36E+03	2.28E+03	1.20E+03
Sr	kg	5.22E+01	5.57E+00	1.68E+01	6.91E+01	7.63E+01	3.35E+01	2.66E+00
TIC as CO3	kg	2.32E+05	4.91E+03	1.21E+05	1.87E+03	1.74E+04	1.10E+04	8.22E+03
TOC	kg	1.85E+04	3.04E+03	1.39E+04	0.00E+00	0.00E+00	4.31E+03	1.15E+03
UTOTAL	kg	2.13E+03	6.24E+03	2.02E+03	5.96E+01	2.57E+00	5.18E+02	2.86E+01
Zr	kg	1.72E+02	8.63E+01	2.78E+02	2.83E+01	9.83E+02	7.76E+02	1.16E+00
106Ru	Ci	2.36E-04	1.16E-05	8.23E-05	4.67E-05	4.25E-04	2.36E-03	1.25E-05
113mCd	Ci	1.82E+02	1.05E+01	7.48E+01	2.91E+01	6.35E+02	2.63E+02	1.30E+01
125Sb	Ci	7.80E+01	5.78E+00	4.07E+01	4.99E+02	6.44E+01	6.43E+00	6.67E+00
126Sn	Ci	6.18E+00	3.25E-01	2.55E+00	4.16E+00	2.81E+01	2.68E+01	4.23E-01
129I	Ci	6.27E-01	4.15E-02	6.19E-02	1.92E-02	1.32E-01	6.31E-02	1.67E-01
134Cs	Ci	5.40E-01	4.52E-02	3.17E-01	5.31E+00	3.00E-01	1.35E-01	1.50E-01
137Cs	Ci	6.35E+05	4.23E+04	3.10E+05	6.63E+04	1.15E+05	6.88E+04	9.51E+04
137mBa	Ci	6.01E+05	4.00E+04	2.93E+05	6.28E+04	1.09E+05	6.51E+04	9.00E+04
14C	Ci	6.61E+01	1.71E+00	4.02E+00	1.40E+00	9.60E+00	5.18E-01	8.87E+00
151Sm	Ci	3.43E+04	1.79E+03	1.41E+04	2.33E+04	1.59E+05	1.48E+05	2.34E+03
152Eu	Ci	9.58E+00	5.41E-01	4.22E+00	6.32E+00	3.59E+01	2.89E+01	5.77E-01
154Eu	Ci	4.24E+02	6.16E+01	4.34E+02	1.65E+03	3.68E+03	5.23E+02	6.42E+01
155Eu	Ci	2.09E+02	1.70E+01	1.34E+02	2.28E+02	8.99E+02	9.59E+02	1.57E+01
226Ra	Ci	4.83E-04	2.16E-05	2.09E-04	8.15E-04	2.98E-03	5.07E-03	3.03E-05
227Ac	Ci	4.26E-03	1.27E-04	1.22E-03	4.68E-03	2.01E-02	2.19E-02	1.46E-04
228Ra	Ci	3.48E-01	4.75E-02	3.34E-01	4.56E-05	1.44E-08	3.55E-02	2.28E-02
229Th	Ci	1.48E-02	1.10E-03	7.76E-03	3.92E-05	4.20E-06	8.57E-04	1.10E-03
231Pa	Ci	1.03E-02	5.94E-04	4.59E-03	6.28E-03	3.63E-02	3.93E-02	8.27E-04
232Th	Ci	7.76E-02	5.80E-03	4.08E-02	9.12E-06	2.44E-09	4.33E-03	4.85E-03
232U	Ci	1.13E+00	3.59E+00	1.16E+00	5.01E-03	6.68E-08	2.04E-01	1.30E-02
233U	Ci	4.63E+00	1.47E+01	4.75E+00	2.07E-02	1.69E-09	8.37E-01	2.77E-01
234U	Ci	7.96E-01	2.34E+00	7.57E-01	2.06E-02	8.81E-04	1.91E-01	2.78E-01
235U	Ci	3.16E-02	9.28E-02	3.00E-02	8.53E-04	3.67E-05	7.69E-03	4.21E-04
236U	Ci	2.56E-02	7.60E-02	2.44E-02	5.64E-04	2.40E-05	6.11E-03	1.81E-03
237Np	Ci	1.14E+00	1.02E-01	7.09E-01	2.91E-02	1.45E-01	7.08E-02	3.13E-01
238Pu	Ci	4.44E+00	1.16E+01	5.58E+00	1.24E+01	2.13E+01	3.76E+01	1.19E-02
238U	Ci	7.11E-01	2.08E+00	6.73E-01	1.99E-02	8.58E-04	1.73E-01	9.50E-03

239Pu	Ci	1.47E+02	3.31E+02	1.96E+02	6.94E+02	5.82E+02	1.07E+03	3.89E-01
240Pu	Ci	2.61E+01	6.14E+01	3.38E+01	1.08E+02	1.11E+02	1.99E+02	6.67E-02
241Am	Ci	4.09E+02	2.50E+02	1.83E+02	3.91E+02	4.08E+03	5.77E+02	4.16E-01
241Pu	Ci	2.35E+02	6.19E+02	2.92E+02	6.80E+02	1.14E+03	2.01E+03	5.30E-01
242Cm	Ci	5.42E-01	2.16E-01	4.03E-01	2.95E-01	3.66E+00	4.41E-01	3.65E-02
242Pu	Ci	1.82E-03	5.10E-03	2.24E-03	4.16E-03	9.25E-03	1.66E-02	3.91E-06
243Am	Ci	1.32E-02	1.25E-02	6.13E-03	7.92E-03	1.27E-01	2.60E-02	1.54E-05
243Cm	Ci	3.97E-02	1.71E-02	3.13E-02	1.66E-02	2.46E-01	3.35E-02	8.39E-05
244Cm	Ci	6.67E-01	5.57E-01	2.29E-01	2.86E-01	6.85E+00	1.14E+00	6.63E-04
3H	Ci	1.70E+02	1.50E+01	1.05E+02	1.34E+00	3.48E+01	1.17E+01	4.96E+01
59Ni	Ci	7.44E+00	3.13E-01	3.10E+00	1.28E+01	4.75E+01	7.60E+01	3.15E-01
60Co	Ci	4.94E+01	2.76E+01	1.81E+01	4.95E+02	5.27E+00	3.83E+00	2.28E+00
63Ni	Ci	7.07E+02	2.97E+01	2.92E+02	1.19E+03	4.53E+03	7.10E+03	2.93E+01
79Se	Ci	1.01E+00	5.38E-02	4.19E-01	6.44E-01	4.50E+00	4.17E+00	7.03E-02
90Sr	Ci	1.74E+05	8.55E+04	1.23E+05	2.49E+06	3.12E+06	5.28E+05	4.67E+01
90Y	Ci	1.74E+05	8.55E+04	1.23E+05	2.49E+06	3.12E+06	5.28E+05	4.67E+01
93mNb	Ci	3.96E+01	1.91E+00	1.50E+01	2.50E+01	1.71E+02	1.62E+02	2.79E+00
93Zr	Ci	4.90E+01	2.66E+00	2.04E+01	2.76E+01	2.07E+02	1.80E+02	3.45E+00
99Tc	Ci	3.25E+02	3.70E+01	1.62E+02	9.91E+00	6.79E+01	7.21E+01	8.62E+01

AW-105	AW-106	AX-101	AX-102	AX-103	AX-104	AY-101	AY-102	AZ-101
4.09E+03	3.93E+04	5.44E+04	4.62E+03	1.52E+04	2.67E+03	2.81E+04	4.13E+04	4.21E+04
1.64E+02	2.54E+02	1.28E+02	7.00E+00	2.66E+01	0.00E+00	6.76E+00	1.52E+02	1.97E+01
8.15E+02	6.27E+02	8.21E+02	2.41E+02	3.46E+02	6.10E+02	1.20E+03	4.63E+03	6.85E+02
9.94E+02	9.24E+03	9.24E+03	1.30E+02	3.02E+03	1.58E+01	3.10E+02	3.51E+02	4.89E+02
9.18E+02	6.76E+03	5.43E+03	1.86E+02	2.22E+03	2.91E+01	1.28E+03	1.51E+03	2.36E+03
6.57E+04	1.28E+03	1.44E+03	3.58E+01	8.20E+02	5.09E+00	1.17E+03	3.71E+02	6.74E+03
2.60E+03	4.63E+02	1.20E+03	3.41E+03	4.54E+03	1.37E+04	3.57E+04	8.69E+04	2.22E+04
0.00E+00	0.00E+00	0.00E+00	1.44E+01	1.40E+01	1.43E+01	1.29E+01	1.13E+02	6.04E-01
1.15E+04	6.48E+03	7.92E+03	2.10E+02	2.07E+03	1.60E+01	4.49E+02	1.83E+03	1.54E+04
7.16E+02	9.16E+01	6.35E+01	4.20E+00	9.09E+01	7.41E+01	1.23E+03	1.12E+03	9.85E+02
1.27E+03	7.70E+01	6.02E+01	3.01E+02	6.17E+02	2.36E+02	2.04E+03	1.15E+04	2.84E+02
1.45E+05	2.97E+05	4.83E+05	2.58E+04	1.10E+05	2.17E+03	9.24E+04	2.40E+05	3.64E+05
2.08E+02	3.68E+02	1.75E+02	1.70E+03	2.71E+02	7.36E+02	1.34E+03	2.11E+03	1.37E+03
1.33E+04	1.35E+05	1.78E+05	5.42E+03	5.30E+04	1.13E+02	2.70E+04	9.65E+04	2.32E+05
5.43E+04	1.92E+05	3.45E+05	3.26E+04	6.47E+04	2.30E+03	2.92E+03	7.76E+02	2.27E+05
4.46E+01	1.34E+02	2.00E+02	2.80E+01	5.67E+02	4.67E+02	9.60E+02	3.52E+03	8.57E+01
4.68E+03	2.23E+04	8.93E+03	2.84E+02	3.27E+03	1.26E+02	4.54E+03	1.54E+04	4.17E+03
2.18E+03	6.43E+02	9.86E+02	8.21E+02	1.16E+03	4.37E+01	4.54E+02	3.01E+02	6.72E+02
2.22E+03	2.25E+04	5.27E+04	6.34E+02	1.09E+04	2.39E+02	5.82E+03	5.79E+03	5.33E+04
3.36E+00	3.60E+01	1.50E+01	7.34E-01	5.37E+01	4.80E+01	6.73E+01	2.31E+02	1.04E+02
1.39E+04	1.25E+05	2.02E+05	1.16E+04	3.36E+04	3.86E+03	1.04E+05	1.55E+05	1.11E+05
5.13E+03	1.24E+04	1.12E+04	7.60E+03	4.37E+03	0.00E+00	5.89E+03	7.53E+03	2.00E+03
1.31E+04	1.14E+03	9.95E+02	6.96E+01	2.49E+02	1.65E+02	5.27E+02	2.99E+03	1.64E+03
9.76E+04	1.19E+02	5.51E+01	5.80E+00	2.20E+02	1.99E+02	6.95E+02	3.17E+01	7.87E+03
4.29E+00	2.81E-04	3.56E-04	3.11E-04	2.95E-04	2.77E-04	6.53E-02	7.61E-03	3.86E+02
2.69E+00	8.24E+01	1.35E+02	6.88E+00	1.60E+02	1.41E+02	1.75E+03	2.59E+01	2.26E+03
3.73E+01	5.04E+01	6.08E+01	8.18E+02	6.29E+01	2.28E+00	2.05E+01	8.31E+00	1.02E+04
4.54E-02	2.73E+00	5.81E+00	2.18E-01	6.77E+00	6.22E+00	2.82E+01	1.49E+00	3.10E+01
4.84E-03	1.80E-01	2.90E-01	1.69E-02	1.45E-01	2.91E-02	9.62E-02	4.54E-02	3.87E-01
9.08E+00	2.38E-01	2.85E-01	1.60E-02	1.77E-01	6.65E-02	2.71E-01	2.14E+02	1.48E+04
3.92E+04	2.46E+05	4.52E+05	4.08E+04	1.12E+05	5.33E+04	7.17E+04	2.17E+05	5.99E+06
3.71E+04	2.32E+05	4.27E+05	3.86E+04	1.06E+05	5.05E+04	6.78E+04	2.05E+05	5.67E+06
5.77E-01	2.70E+01	4.64E+01	2.81E+00	1.31E+01	2.12E+00	9.64E-01	6.84E-01	6.70E+00
2.36E+02	1.39E+04	3.21E+04	1.20E+03	3.82E+04	3.52E+04	4.30E+05	8.10E+03	2.10E+05
8.50E-01	4.22E+00	8.13E+00	2.82E+00	8.92E+00	7.94E+00	2.50E+02	6.25E+01	3.96E+02
2.73E+01	3.81E+02	6.94E+02	8.72E+01	2.54E+03	1.12E+03	4.70E+03	6.80E+03	1.37E+04
8.28E+01	1.11E+02	2.59E+02	6.07E+02	3.46E+02	7.93E+02	2.28E+03	5.55E+03	1.77E+04
5.80E-07	1.72E-04	6.76E-04	1.61E-04	6.89E-04	6.59E-04	1.02E-02	3.76E-03	7.01E-04
6.47E-06	1.70E-03	4.87E-03	6.00E-04	4.62E-03	4.46E-03	5.69E-02	1.37E-02	7.82E-03
1.04E-10	1.98E-01	2.73E-01	3.02E-02	1.03E-01	3.19E-09	4.54E-02	3.42E-02	3.11E-03
1.26E-08	8.29E-03	1.16E-02	7.01E-04	2.40E-03	9.30E-07	7.86E-04	7.07E-06	5.85E-06
1.91E-05	4.64E-03	9.72E-03	3.93E-04	9.13E-03	8.04E-03	7.46E-02	2.09E-03	2.29E-02
9.73E-11	4.36E-02	6.09E-02	3.68E-03	2.06E-03	5.39E-10	4.06E-02	6.02E-02	8.12E-03
4.54E-01	3.02E-01	5.69E-01	3.08E-02	9.11E-02	4.30E-06	1.06E-01	3.24E-04	2.78E-02
1.85E+00	1.24E+00	2.33E+00	1.26E-01	9.21E-02	1.08E-07	4.35E-01	4.72E-06	1.13E-01
6.29E+00	4.21E-01	3.74E-01	2.59E-02	1.22E-01	5.67E-02	1.93E-01	1.32E+00	7.88E-01
2.39E-01	1.74E-02	1.48E-02	1.04E-03	3.55E-03	2.36E-03	7.83E-03	5.09E-02	3.00E-02
5.02E-01	1.49E-02	1.21E-02	8.47E-04	4.19E-03	1.55E-03	6.63E-03	9.58E-02	6.38E-02
3.53E-02	2.97E-01	5.30E-01	3.09E-02	1.90E-01	3.22E-02	2.13E-01	4.82E+00	1.35E+01
5.16E+01	2.91E+01	6.77E+00	1.83E+01	3.47E+00	1.03E+01	1.94E+02	5.27E+02	1.33E+02
4.38E+00	3.81E-01	3.32E-01	2.32E-02	8.33E-02	5.52E-02	1.76E-01	1.02E+00	5.45E-01

4.50E+02	8.61E+02	1.95E+02	2.40E+02	9.53E+01	2.82E+02	5.13E+02	1.64E+03	1.15E+03
1.35E+02	1.46E+02	3.61E+01	6.21E+01	1.89E+01	5.38E+01	1.55E+02	3.56E+02	3.47E+02
3.68E+02	1.32E+02	2.30E+02	1.10E+02	1.01E+03	9.51E+02	8.79E+03	7.62E+03	2.55E+04
3.97E+03	1.50E+03	3.62E+02	2.63E+02	1.86E+02	5.53E+02	2.82E+03	4.44E+03	1.02E+04
3.76E-01	1.90E-03	2.30E-01	1.82E-01	8.93E-01	8.37E-01	1.17E+01	1.40E+01	2.30E+01
2.08E-02	1.32E-02	2.97E-03	1.03E-02	1.51E-03	4.48E-03	2.80E-02	4.28E-02	5.35E-02
2.93E-02	5.64E-03	1.11E-02	8.07E-03	3.23E-02	2.91E-02	8.83E-01	5.61E-01	5.40E+00
4.36E-02	3.85E-05	1.80E-02	1.69E-02	5.98E-02	5.62E-02	1.19E+00	1.27E+00	3.36E+00
5.23E-01	1.00E-03	5.03E-01	4.09E-01	1.67E+00	1.57E+00	4.08E+01	3.03E+01	7.53E+01
3.15E+01	4.36E+01	7.87E+01	4.75E+00	3.89E+01	7.70E+00	4.05E+00	2.06E+01	5.92E+01
1.45E-01	2.49E+00	1.04E+01	4.66E+00	1.09E+01	1.05E+01	1.58E+02	1.11E+02	2.68E+01
6.66E+01	2.39E+01	4.04E+01	1.49E+02	1.01E+02	1.34E+02	4.40E+02	1.10E+01	1.15E+03
1.59E+01	2.18E+02	9.74E+02	4.39E+02	1.04E+03	1.00E+03	1.48E+04	1.04E+04	2.95E+03
7.20E-03	5.21E-01	9.38E-01	3.59E-02	1.09E+00	4.93E-02	1.38E+01	1.47E-01	4.94E+00
3.54E+04	4.97E+04	1.61E+05	2.32E+05	4.84E+05	2.21E+06	1.38E+06	5.28E+06	4.95E+06
3.54E+04	4.97E+04	1.61E+05	2.32E+05	4.84E+05	2.21E+06	1.38E+06	5.28E+06	4.95E+06
2.07E-01	1.65E+01	3.69E+01	1.28E+00	4.10E+01	3.78E+01	5.00E+02	9.14E+00	1.93E+02
3.46E-01	2.06E+01	4.40E+01	1.77E+00	5.03E+01	4.57E+01	6.10E+02	1.06E+01	3.11E+02
2.41E+00	1.16E+02	1.50E+02	8.76E+00	1.61E+02	9.37E+01	5.60E+01	3.33E+01	1.25E+03

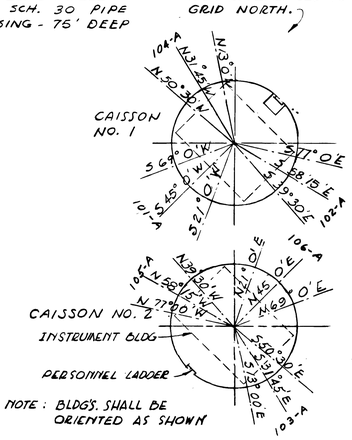
Selected pages from H-2-31880, 1968, "241-A Tank Farm Leak Detection System Plan Section Detail," H.E. Bovay, Jr., Consulting Engineers, Richland, Washington.



LATERAL	℄ ELEV.
TANK NO	℄ ELEV. @ CAISSON WALL
101	626.59
102, 104	625.88
103, 105	624.88
106	623.59

TYPICAL SECTION

1/8" = 1'-0"



LATERALS LAYOUT

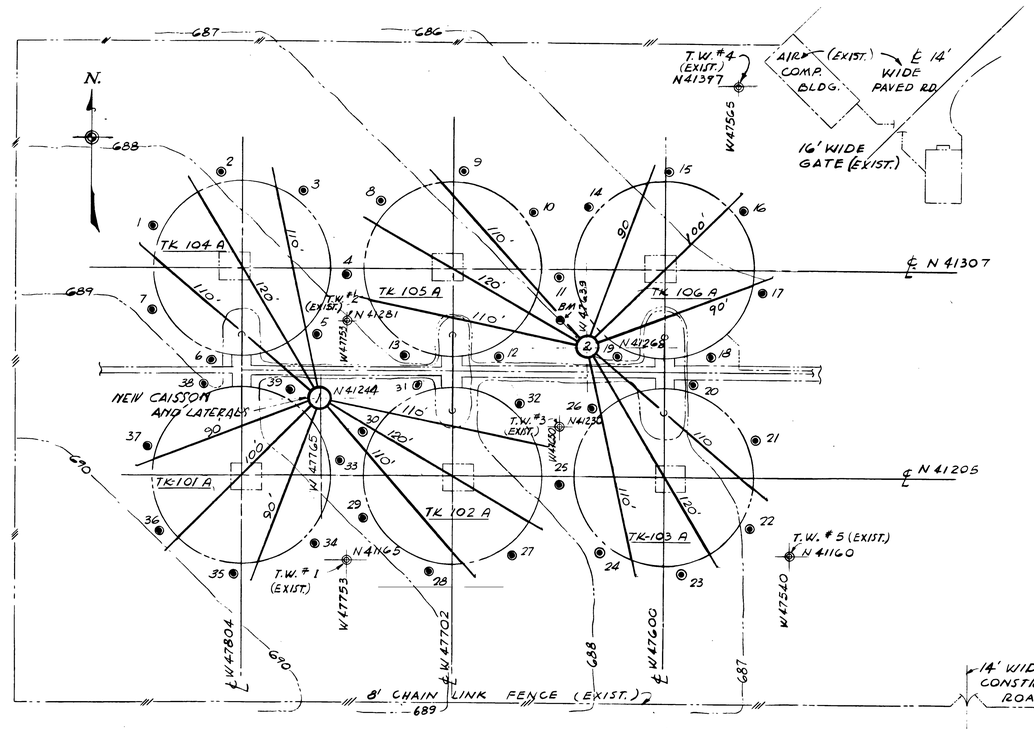
NO SCALE

241-A VERTICAL DETECTION WELL LOCATIONS

WELL	LAT	DEP		WELL	LAT	DEP.	
1	N 41328	W 47847		21	N 41223	N 47552	
2	41355	47815		22	41180	47558	
3	41345	47774		23	41158	47591	
4	41304	47752		24	41168	47631	
5	41275	47767		25	41201	47651	
6	41262	47820		26	41239	47635	
7	41287	47848		27	41166	47674	
8	41340	47737		28	41158	47713	
9	41355	47697		29	41184	47745	
10	41335	47663		30	41226	47745	
11	41304	47650		31	41250	47720	
12	41264	47680		32	41240	47669	
13	41263	47722		33	41213	47756	
14	41338	47637		34	41172	47769	
15	41356	47598		35	41157	47808	
16	41337	47562		36	41178	47844	
17	41296	45552		37	41224	47849	
18	41264	47577		38	41250	47822	
19	41264	47623		39	41247	47781	
20	41250	47588					

GENERAL NOTES

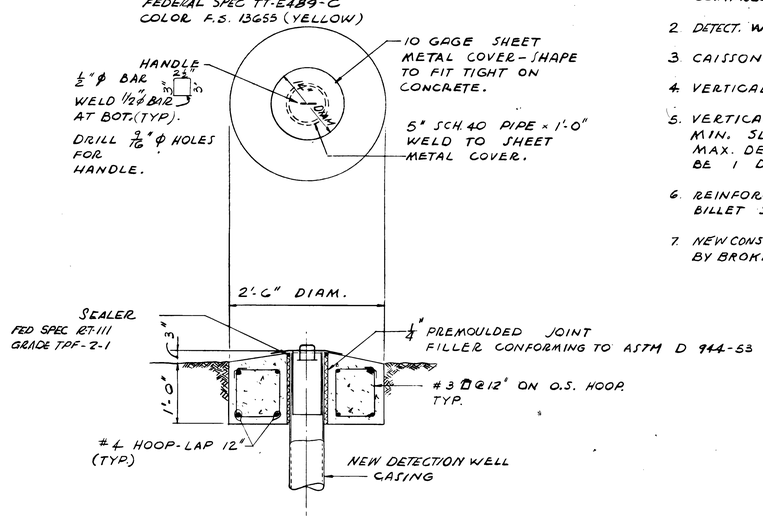
1. ALL CONCRETE SHALL BE 3000 PSI @ 28 DAY COMPRESSIVE BREAK. MAX. SIZE AGGREGATE SHALL BE 1½".
2. DETECT. WELLS SHALL BE PLUMB WITHIN 1 FT.
3. CAISSON CENTERLINES ± 0.1 FT. - LOCATION VARIANCE
4. VERTICAL ELEVATION OF LATERALS @ CAISSON ± 0.05 FT.
5. VERTICAL ALIGNMENT OF LATERALS - MAX SLOPE -2½%. MIN. SLOPE -½%. MAX. DEVIATION FROM HORIZONTAL ALIGNMENT SHALL BE 1 DEGREE.
6. REINFORCING STEEL SHALL BE INTERMEDIATE GRADE BILLET STEEL CONFORMING TO ASTM A15-58T.
7. NEW CONSTRUCTION INDICATED BY SOLID LINES - OLD CONSTRUCTION BY BROKEN LINES.



PLOT PLAN

241-A TANK FARM 200-E AREA

SCALE 1" = 30'



DETAIL (A)

H-2-31881

NO.	DESCRIPTION	REV. BY DATE	APP'D BY	FOR	DATE
2	PHOTO-RETRACED (FCN 17754)				
1	AS BLT				

REVISIONS

REF. NO.	DWG. NO.	DRAWING TITLE
5	H2-31882	SHT. 3 UNDERGR'D ELECT.
4	HWS-8158	MONITORING WELL SPECS.
3	H-2-31882	LEAK DETECT. SYSTEM-DETAILS
2	H-2-31881	241-SX TK FARMS-LEAK DETECT.
1	HWS-8154	CONSTRUCTION SPECIFICATION

REFERENCE DRAWINGS

NEXT USED ON H-2-31881 & H2-31882

QTY.	PT. NO.	DESCRIPTION

CHECK PRINT — COMMENT PRINT — ISSUE NO. — DATE — ISSUE NO. 1st — DATE 12/14/61

APPROVED FOR CONST. — BY — FOR — DATE — REV.

APPROVED FOR PURCHASE — BY — FOR — DATE

SCALE AS NOTED

APPROVED FOR DESIGN — BY — FOR — DATE

DRAWN M.D.H. BOVAY — DATE 6-28-61
CHECKED J.D. BOVAY — DATE 6/61
ISSUED — DATE 7/6/61
DES. ENG. HANSEN (BOVAY) — DATE 6-61
PROJECT CAC-928 — INST. NO. 0168
CLASSIFIED BY T. Delaney — DATE June 28, 61
CLASSIFICATION NONE

H. E. BOVAY, JR., CONSULTING ENGINEERS
SPOKANE HOUSTON BATON ROUGE
RICHLAND OFFICE BLDG 713-A

U. S. ATOMIC ENERGY COMMISSION - HANFORD ATOMIC PRODUCTS OPERATION
GENERAL ELECTRIC

241-A TANK FARM LEAK DETECTION SYSTEM PLAN-SECTION-DETAIL

BLDG. NO. 241-A — INDEX NO. 0402

DWG. NO. H-2-31880 — SHT. NO. — REVISION

H-2-31880 — SHEET 1/1 — REV. 2

Selected pages from HW-79805, 1963, "Geology Underlying the 241-AX Tank Farm," General Electric Company, Richland, Washington

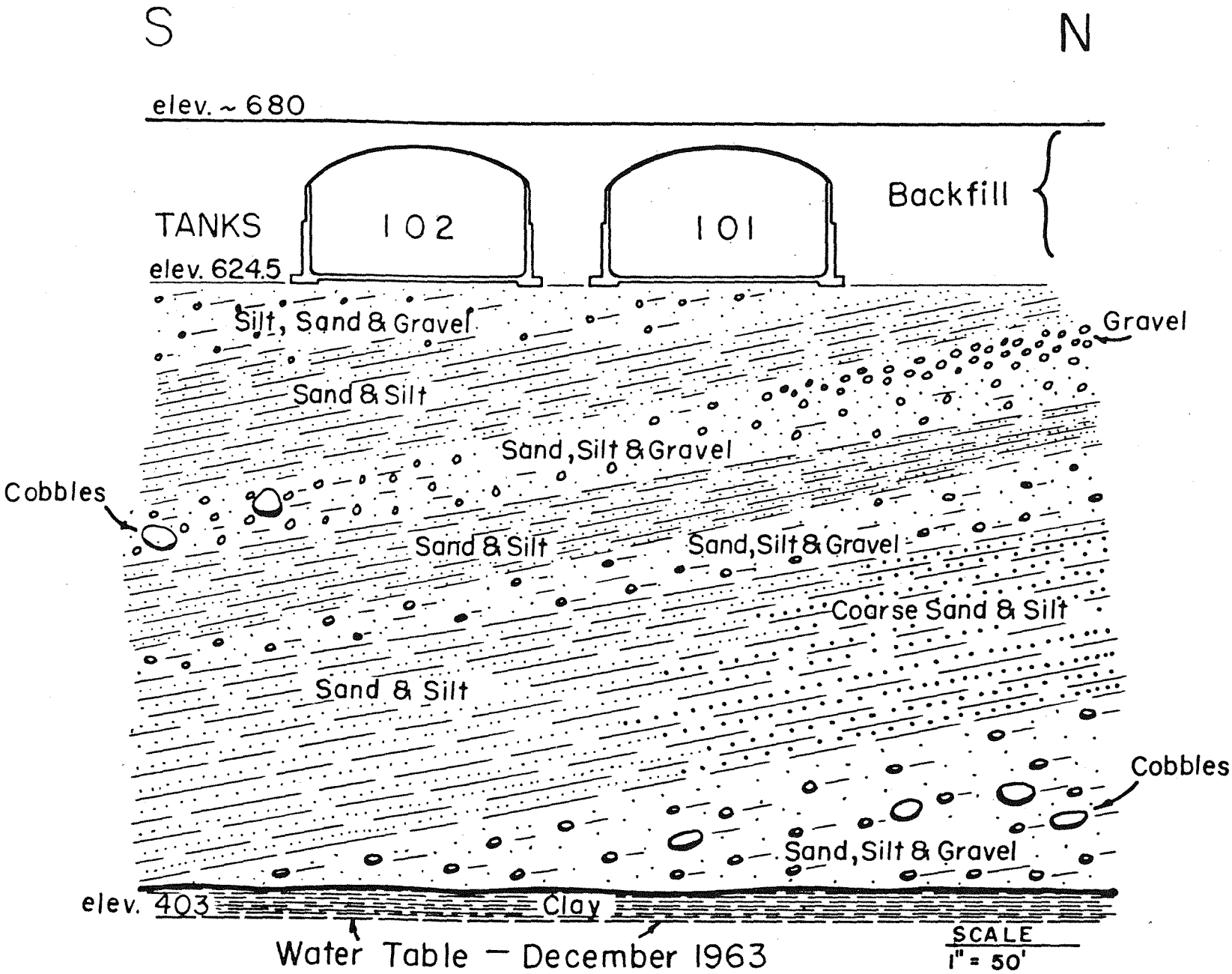


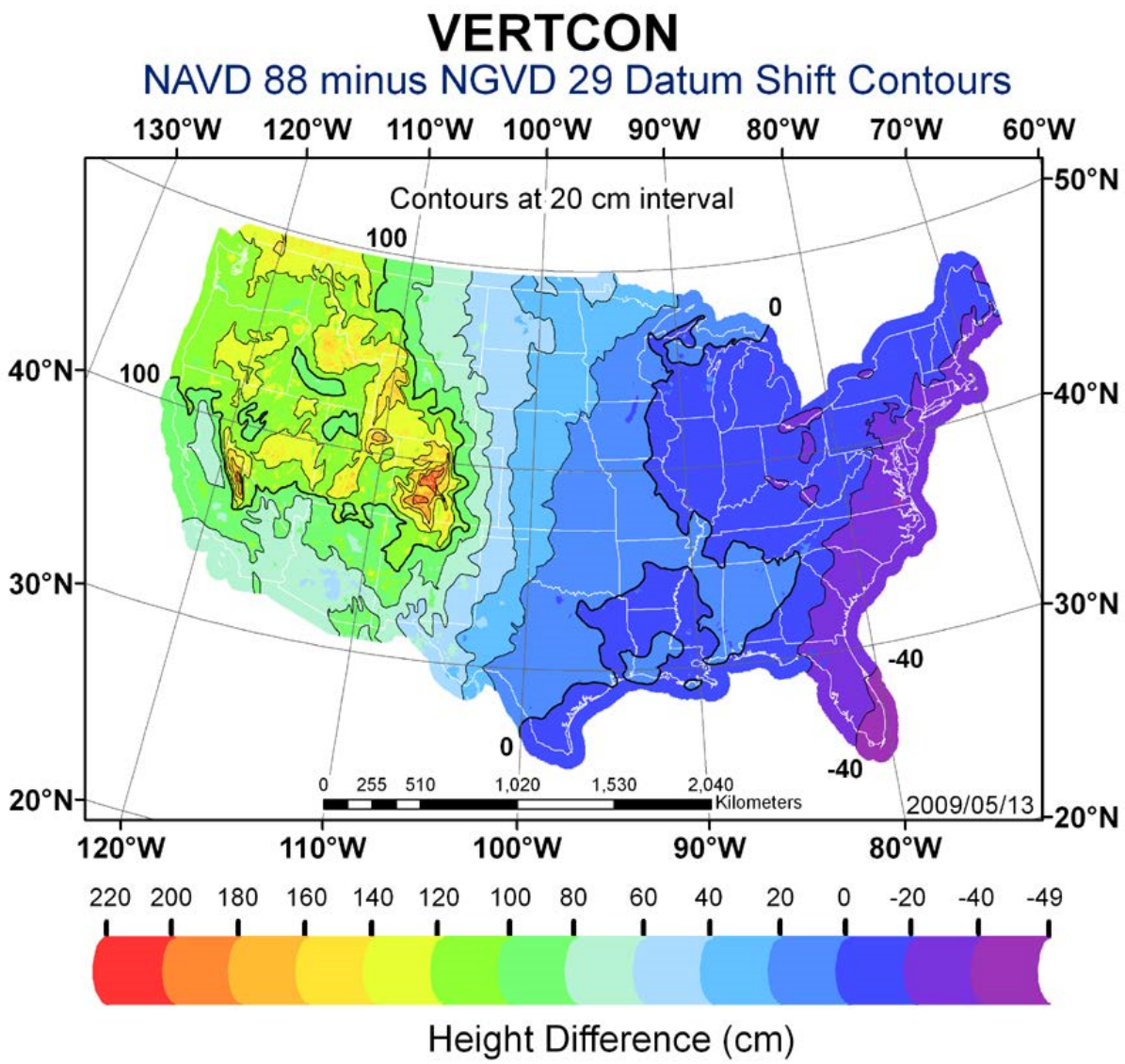
FIGURE 3

Cross Section Through The 241-AX Tank Farm

AEC-GE RICHLAND, WASH

HW-79805

Selected pages from VERTCON – North American Vertical Datum Conversion, National Geodetic Survey, Queried 05/19/2015, [VERTCON, NAVD 88 minus NGVD 29 Datum Shift Contours], http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html.


VERTCON
NAVD 88 minus NGVD 29 Datum Shift Contours
130°W 120°W 110°W 100°W 90°W 80°W 70°W 60°W
50°N
40°N
30°N
20°N
Contours at 20 cm interval
100
100
0
0
-40
-40
0 255 510 1,020 1,530 2,040
Kilometers
2009/05/13
120°W 110°W 100°W 90°W 80°W
220 200 180 160 140 120 100 80 60 40 20 0 -20 -40 -49
Height Difference (cm)

Selected pages from PNNL-15782, 2006, "STOMP, Subsurface Transport Over Multiple Phases, Version 4.0, User's Guide," Pacific Northwest National Laboratory, Richland, Washington

Table 4.3. STOMP Initial Conditions Default Values

Initial Field Variable	Symbol	Default Value
Temperature	T	20.D+0
Pressure of phase j	P_j	101325.D+0
Saturation of phase j	s_j	0.D+0
Mole fraction of component i in phase j	χ_j^i	0.D+0
Solute concentration in phase γ	C_γ	0.D+0
Salt concentration in phase γ	S_γ	0.D+0

No initial saturation options are allowed for the three-phase, aqueous-NAPL-gas, operational modes (e.g., *STOMP-WO (Water-Oil), STOMP-WOA(Water-Oil-Air)*). For these three-phase operational modes, initial saturations must be declared by specifying initial gas, aqueous, and NAPL pressures. If the initial NAPL pressure is assigned a value below the critical point, which signifies no NAPL, then the initial NAPL pressure is reset within the simulator to the critical pressure. Therefore, conditions without NAPL can be specified by initializing the NAPL pressure to any value below the aqueous pressure. Initial conditions may be declared repeatedly for a node with the last definition being applied. Initial conditions for solutes are expressed in terms of solute per unit volume where the volume can refer to the total node volume (*Volumetric*), the aqueous-phase volume (*Aqueous Volumetric*), the gas-phase volume (*Gas Volumetric*), or the NAPL volume (*NAPL Volumetric*). Solute units are undefined and can be expressed as the user chooses (e.g., Ci, pCi, gm, kg, mol, kgmol). Although units for expressing solute quantity may vary among solutes, units must be consistent for a single solute among all input data entries.

The gradient utilities of the initial condition card are invaluable and should be used to advantage when possible. Gradients to the initial conditions allow the user to specify that the initial value of field variables varies along one or more directions in the physical domain. The initial condition variable assigned to an initial condition domain applies to the node with the lowest *x*-, *y*-, and *z*-direction indices. If non-zero gradient values are specified, then the initial condition values will vary according to the gradients specified for each physical direction. Default values for the initial condition gradients are zero, indicating no variation. Gradient values are applicable only over the state initial condition domain. An example application of the initial condition gradient utility occurs for problems which start with hydrostatic conditions. For these problems, the pressure at the lowest *z*-direction node positions would be entered with a *Z-Dir. Gradient* that is equal to the product of the fluid's density times gravitational acceleration. For water at 20°C, a z–direction gradient of -9793.5192 1/m will yield constant head conditions, which would be equivalent to hydrostatic conditions. This approach could be used to locate the position of a water table under no-recharge equilibrium conditions given the rock/soil saturation function properties and knowledge of a single pressure using an *Initial Condition* execution mode simulation.

For the Reactive Transport modules, this card has been modified to allow for reactive species concentrations to be initialized. Initial aqueous or solid species concentrations can be entered as node volume molar, aqueous molar or aqueous molal. Initial gas species concentrations can be entered as node

Selected pages from RPP-14430, 2003, "Subsurface Conditions Description of the C and A-AX Waste Management Area," Rev. 0, CH2M Hill Hanford Group, Inc., Richland, Washington.

Two factors likely contribute to the measurement discrepancies. First, since the early 1990s the water table has dropped from the more permeable Hanford formation into the less permeable undifferentiated Plio-Pleistocene/Ringold Unit. The higher conductivity measurements were taken when the water table was elevated and reflected the influence of the Hanford formation on the overall permeability of the unconfined aquifer. Second, slug tests involve a more limited areal extent than pumping tests and tend to provide lower measurements. Slug tests apply a limited stress to the aquifer and are valid over a limited range of conductivities (Thorne and Newcomer 1992). Because the water table is expected to remain in the less permeable stratigraphic unit, an estimated hydraulic conductivity range of 15 to 150 ft (5 to 50 m) per day is estimated.

2.4.2.4 Porosity. Porosity is generally estimated to be about 30% for unconsolidated, coarse-grained sediments at the DOE Hanford Site (Hartman 1999). Because it has not been possible to collect intact core from the aquifer during past drilling, direct methods of determining porosity have not been used. The lack of direct measurements combined with the cobble to boulder grain size of the aquifer suggests 30% may be approximately correct or slightly high value for porosity. Where boulders and cobbles are present and mixed with sand and gravels in the interstices of the larger cobbles a value closer to 20% may be more appropriate for effective porosity (Eckis 1934, Evenson et al., 1962).

2.4.2.5 Flow Direction. The hydraulic gradient is relatively gentle across the 200 East Area. With about 6-in. (15 cm) across the C WMA and 2.4 in. (6 cm) of change across the A-AX WMA , the exclusive use of discrete water elevations to determine flow direction is not recommended. Although this low gradient is caused, in part, by the dissipating groundwater mound under B-Pond, it is primarily due to the high aquifer transmissivity in the 200 East Area with respect to upgradient regions farther west where transmissivity is considerably less. Before formation of the groundwater mound beneath B-Pond, the groundwater flowed regionally to the southeast towards the 300 Area. Recent interpretations of current flow direction show a southwesterly flow from the C WMA and turning more southeasterly at the A-AX WMA where the aquifer is more than twice as thick and the regional southeasterly flow pattern becomes dominant (Williams et al., 2000, Hartman et al., 2002). These patterns are consistent with regional flow directions.

Although the predominant flow directions at these two WMAs are consistent with the regional flow directions and plume trends, as evidenced over miles, they can be misleading when determining the local flow anomalies across these small sites that are 500 ft wide (152.4 m). Some suggestion of the complexity of flow patterns in the 200 East Area is shown by direct measurements shown in Figure 2-13. The large variation in flow directions may be somewhat exaggerated because the effects of well design and rapid changes in barometric pressure, which are not accounted for in Figure 2-13. It is known that wells south of PUREX can have large changes in flow direction in a single day because of their barometric efficiency.

Until this year, the flow direction at these two WMAs had been determined exclusively from gradient calculations based on local water elevations. Unfortunately, across the 200 East Area, the differences in water elevation between wells are small, on the order of a few inches. The combined errors from water level measurements, survey elevations and borehole deviations from

about 230,000 gal of contaminated water from this tank – likely more than enough water to drive mobile constituents such as Tc-99 to the water table. Yet, the groundwater monitoring program has not detected groundwater contamination that can be associated with the A Tank Farm. Thus, a 10 kgal leak volume for tank A-105 is highly unrealistic. Thus, it is probable the volume of PUREX high-level supernatant lost from tank A-105 is less than 1 kgal. Table 4-1 reports an inventory for a nominal 1-kgal loss from tank A-105.

The tank A-104 leak occurred similarly to the tank A-105 leak. Enhanced gamma activity was note in lateral 14-04-02 in April 1975 followed by gamma hits at other locations under the tank. As with tank A-105 conditions, little or no contamination from the A-104 leak is found in the surrounding monitoring boreholes. In 1975, the waste stream in tank A-104 was PUREX sludge supernate (produced from PUREX sludge washing prior to acid dissolution for Sr-90 recovery). The Cs-137 activity in the PUREX sludge supernatant was about an order of magnitude lower than in the PUREX supernatants (Larson 1967). The estimated leak volume is very small (500 to 2,500 gallons according to Hanlon [1999]) and cannot be corroborated. Unlike the tank A-105 leak there was little opportunity for subsequent contaminant migration because water was not added to the tank after the leak.

The extent of subsequent migration of mobile constituents in waste leaked from tanks A-105 and A-104 in the vadose zone is not known. It is postulated that vertical migration has been limited by the fact that waste apparently was disposed directly underneath the tanks within the moisture shadow created by the tanks themselves. Without significant infiltration, migration beyond a few feet is unlikely.

Table 4-1. Tank Leak Inventory Estimates for A, AX, and C Tank Farms.
(3 sheets)

Tank	A-104	A-105	C-105	UPR-200-E-81	UPR-200-E-82	UPR-200-E-86
Leak Vol.	2.0 kgal	1 kgal	1 kgal	36 Kgal	2,600 gal	17,400 gal
Analyte	kg	kg	kg	kg	kg	kg
Na	2.44E+02	4.10E+02	4.49E+02	5.10E+03	1.17E+03	2.14E+03
Al	4.60E+00	7.14E-01	1.52E+01	2.32E+03	3.96E+01	3.93E+01
Fe	8.44E-01	1.80E+00	2.69E+00	1.53E+01	6.99E+00	7.41E+00
Cr	6.69E+00	6.71E+00	9.82E+00	2.18E+01	2.55E+01	5.88E+01
Bi	1.88E-02	4.42E-03	9.66E-02	0.00E+00	2.51E-01	1.60E-01
La	1.41E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg	5.58E-04	9.06E-05	1.85E-03	2.75E-01	4.82E-03	4.84E-03
Zr	4.43E-05	1.06E-04	7.57E-04	0.00E+00	1.97E-03	4.27E-04
Pb	9.38E-02	1.34E-02	2.94E-01	4.54E+01	7.65E-01	8.14E-01
Ni	7.96E-01	1.70E+00	2.53E+00	1.23E+01	6.59E+00	6.99E+00
Sr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn	1.10E+00	3.40E-02	2.72E-01	0.00E+00	7.06E-01	9.67E+00
Ca	2.72E+00	5.80E+00	8.70E+00	4.93E+01	2.26E+01	2.38E+01
K	2.26E+00	2.99E+00	2.97E+00	1.34E+01	7.72E+00	1.98E+01
NO3	1.38E+02	1.51E+02	3.15E+02	5.79E+03	8.18E+02	1.21E+03

Table 4-1. Tank Leak Inventory Estimates for A, AX, and C Tank Farms. (3 sheets)

Tank	A-104	A-105	C-105	UPR-200-E-81	UPR-200-E-82	UPR-200-E-86
Leak Vol.	2.0 kgal	1 kgal	1 kgal	36 Kgal	2,600 gal	17,400 gal
Analyte	kg	kg	kg	kg	kg	kg
NO2	1.65E+02	3.49E+02	2.69E+02	1.82E+03	6.98E+02	1.45E+03
CO3	6.62E+01	2.23E+01	6.46E+01	7.40E+01	1.68E+02	5.79E+02
PO4	1.67E+01	1.30E-01	1.64E+00	0.00E+00	4.25E+00	1.48E+02
SO4	5.90E+01	1.82E+02	8.64E+01	1.66E+02	2.25E+02	5.19E+02
Si	7.20E+00	1.43E+01	1.84E+01	0.00E+00	4.79E+01	1.71E+02
F	5.79E-02	1.76E-02	4.41E-01	0.00E+00	1.15E+00	4.89E-01
Cl	5.10E+00	1.23E+01	1.14E+01	5.59E+01	2.95E+01	4.46E+01
DBP	9.27E-02	1.29E+01	4.33E+01	0.00E+00	1.12E+02	0.00E+00
Butanol	3.27E-02	4.54E+00	1.52E+01	0.00E+00	3.96E+01	0.00E+00
TBP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NPH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-Total	4.26E+00	5.62E+00	7.06E+00	1.30E+02	1.83E+01	3.73E+01
Analyte	Ci	Ci	Ci	Ci	Ci	Ci
H-3	4.68E-02	1.83E+00	6.62E-01	9.95E-02	1.72E+00	3.89E-01
C-14	1.01E-01	3.77E-01	2.76E-01	1.40E-02	7.17E-01	8.86E-01
Ni-59	1.09E-02	4.67E-02	3.50E-02	3.93E-03	9.11E-02	9.59E-02
Ni-63	1.07E+00	4.66E+00	3.39E+00	3.96E-01	8.81E+00	9.39E+00
Co-60	1.02E-01	4.76E-01	1.95E-01	2.03E-02	5.08E-01	8.99E-01
Se-79	1.51E-02	3.00E-02	3.84E-02	3.10E-03	9.99E-02	1.32E-01
Sr-90	2.55E+02	5.10E+02	6.55E+02	3.29E+02	1.70E+03	2.25E+03
Y-90	2.56E+02	5.10E+02	6.53E+02	3.29E+02	1.70E+03	2.25E+03
Zr-93	7.54E-02	1.50E-01	1.91E-01	1.45E-02	4.97E-01	6.61E-01
Nb-93m	5.26E-02	1.05E-01	1.34E-01	1.06E-02	3.48E-01	4.63E-01
Tc-99	7.08E-01	2.67E+00	1.93E+00	1.02E-01	5.01E+00	6.22E+00
Ru-106	3.75E-05	5.45E-05	6.76E-06	3.36E-05	1.76E-05	3.31E-04
Cd-113m	4.52E-01	8.74E-01	1.05E+00	7.07E-02	2.74E+00	3.97E+00
Sb-125	3.84E-01	2.05E+00	4.94E-01	1.11E-01	1.28E+00	3.37E+00
Sn-126	2.26E-02	4.48E-02	5.76E-02	4.74E-03	1.50E-01	1.98E-01
I-129	1.37E-03	5.14E-03	3.73E-03	1.97E-04	9.69E-03	1.20E-02
Cs-134	1.74E-02	1.06E-01	1.54E-02	7.34E-03	3.99E-02	1.53E-01
Cs-137	2.37E+03	9.60E+03	6.33E+03	3.79E+02	1.65E+04	2.08E+04
Ba-137m	2.24E+03	9.12E+03	5.97E+03	3.58E+02	1.55E+04	1.96E+04
Sm-151	5.26E+01	1.05E+02	1.34E+02	1.12E+01	3.48E+02	4.63E+02
Eu-152	1.70E-02	5.84E-02	3.03E-02	2.56E-03	7.89E-02	1.49E-01
Eu-154	2.19E+00	6.26E+00	4.29E+00	4.01E-01	1.12E+01	1.92E+01
Eu-155	1.11E+00	4.21E+00	1.71E+00	1.84E-01	4.46E+00	9.79E+00

Table 4-1. Tank Leak Inventory Estimates for A, AX, and C Tank Farms. (3 sheets)

Tank	A-104	A-105	C-105	UPR-200-E-81	UPR-200-E-82	UPR-200-E-86
Leak Vol.	2.0 kgal	1 kgal	1 kgal	36 Kgal	2,600 gal	17,400 gal
Analyte	kg	kg	kg	kg	kg	kg
Ra-226	4.67E-07	9.27E-07	1.19E-06	2.01E-07	3.10E-06	1.32E-06
Ra-228	4.24E-07	5.50E-08	1.34E-06	2.11E-04	3.48E-06	1.67E-06
Ac-227	2.71E-06	5.40E-06	7.22E-06	4.93E-05	1.88E-05	2.38E-05
Pa-231	1.51E-05	3.00E-05	4.00E-05	2.74E-04	1.04E-04	1.32E-04
Th-229	9.60E-08	3.02E-08	6.09E-07	9.51E-05	1.58E-06	7.74E-07
Th-232	8.50E-07	1.18E-07	2.87E-06	4.51E-04	7.46E-06	7.14E-06
U-232	4.77E-04	6.88E-06	9.18E-05	8.82E-03	2.39E-04	4.19E-03
U-233	1.84E-03	2.66E-05	3.59E-04	3.43E-02	9.33E-04	1.62E-02
U-234	1.48E-03	1.90E-03	2.33E-03	4.62E-02	6.06E-03	1.29E-02
U-235	6.07E-05	7.95E-05	9.90E-05	1.89E-03	2.57E-04	5.35E-04
U-236	4.05E-05	4.67E-05	4.55E-05	1.38E-03	1.18E-04	3.55E-04
U-238	1.42E-03	1.87E-03	2.36E-03	4.36E-02	6.13E-03	1.24E-02
Np-237	2.22E-03	6.50E-03	7.70E-03	7.63E-04	2.00E-02	1.94E-02
Pu-238	1.40E-02	4.18E-03	2.80E-03	2.88E-02	7.28E-03	1.24E-01
Pu-239	5.94E-01	1.31E-01	1.77E-01	1.20E+00	4.61E-01	5.24E+00
Pu-240	9.77E-02	2.35E-02	2.68E-02	2.14E-01	6.97E-02	8.60E-01
Pu-241	1.01E+00	3.00E-01	2.08E-01	2.30E+00	5.41E-01	8.93E+00
Pu-242	4.96E-06	1.64E-06	7.69E-07	6.49E-06	2.00E-06	4.37E-05
Am-241	2.26E-01	4.49E-01	5.75E-01	8.70E-02	1.50E+00	1.98E+00
Am-243	4.99E-06	1.11E-05	5.81E-06	9.18E-07	1.51E-05	4.36E-05
Cm-242	4.08E-04	1.56E-03	6.06E-04	3.70E-05	1.58E-03	3.56E-03
Cm-243	2.31E-05	1.12E-04	1.61E-05	1.02E-06	4.19E-05	2.00E-04
Cm-244	7.50E-04	1.18E-03	5.00E-04	3.49E-05	1.30E-03	6.61E-03

All radionuclides decayed to 1/1/1994

4.2.3 C and A-AX WMA Transfer Line Leak Data Integration and Interpretation

Numerous transfer line leaks have occurred in the C and A-AX WMAs. Among the tanks, spectral gamma data suggest that the most contaminating leaks occurred between tanks C-104 and C-105, between tanks C-108 and C-109, between A-101 and A-102, between AX-103 and AX-104, and between tanks AX-101 and AX-103. The data that characterize these events (primarily spectral gamma data) was summarized in Chapter 3. In addition, three transfer line leaks near three diversion boxes (241-CR-151, 241-C-151 and 241-C-152) have been reported as unplanned releases in the C WMA. Of these, the two near diversion boxes 241-C-152 (UPR-200-82) and 241-C-151 (UPR-200-86) are the most significant sources of contamination (see Section 4.3). Other unplanned releases were also reported, but their descriptions suggest a minimal vadose zone contamination outcome.

Selected pages from RPP-35484, 2008, "Field Investigation Report for Waste Management Areas C and A-AX," Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington

The discharges from the above-named facilities raised the water table underlying WMAs C and A-AX and added contaminants to the unconfined aquifer. Groundwater monitoring wells were routinely constructed for liquid discharge facilities and provided some measurement of these effects. Groundwater samples were taken frequently from a few monitoring wells between the mid 1950s and the present and provided some insight into the groundwater impacts from these operations. Early on, the data most consistently taken were water elevation (head data), nitrate concentrations, and gross beta measurements.

The earliest groundwater contamination in the area of the A and AX tank farms, as indicated by data in the Hanford Environmental Information System database, was October 1951, when gross beta was 140,000 pCi/L in well 299-E25-1, located inside the A tank farm, and 160,000 pCi/L in downgradient well 299-E25-2, located east of the A tank farm. Neither well was resampled for six yr. In 1957, gross beta had reached 28,000,000 pCi/L in well 299-E25-1 and 210,000 pCi/L in well 299-E25-2. These high beta concentrations were accompanied by high concentrations of nitrate and cobalt-60. Throughout most of the 1960s, groundwater sampling in these wells was sparse. By the time sampling resumed on a regular basis, the high concentration plumes had moved away from the wells, decayed away, or both. The source for the contamination in the WMA A-AX area in the early 1950s is not known, but cannot be the WMA itself because the A and AX tank farms were not used until 1956 and 1965, respectively.

About 1960s a strong nitrate peak is observed in all well locations surrounding WMA A-AX, and significantly higher concentrations (approximately 1.0×10^6 μ/L) occur at monitoring wells 299-E26-4, 299-E25-8, and 299-E25-2, which were located at the primary condensate discharge facilities east of WMA A-AX (cribs 216-A-24 and 216-A-8). The other monitoring well peak concentrations are about a factor of ten lower. This comparison strongly indicates that these cribs are the source of the observed nitrate, at least on the east side of WMA A-AX.

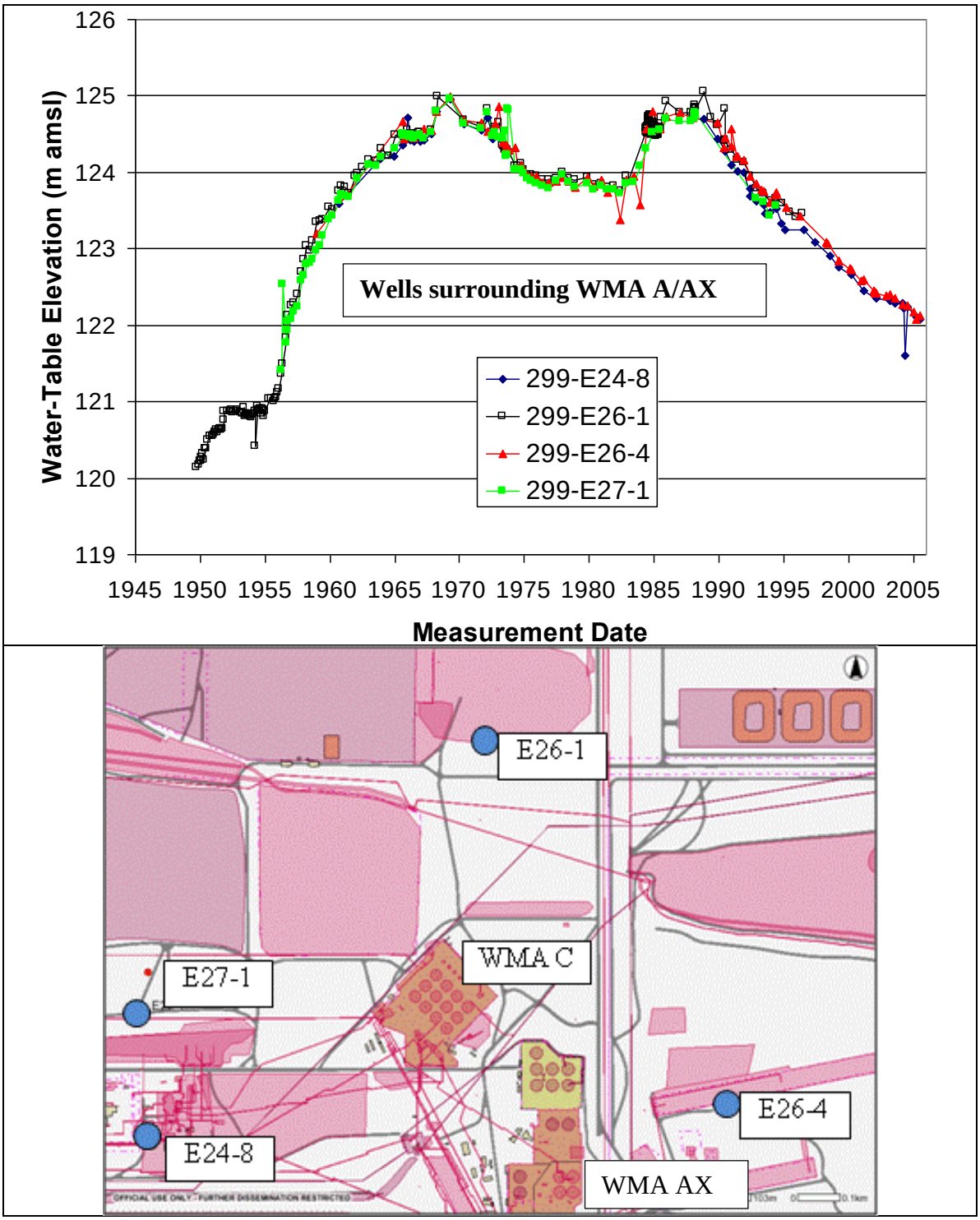
Future groundwater contamination is expected to occur in the unconfined aquifer underlying WMAs C and A-AX. Field work described in this FIR and historical data consistently indicate that releases from individual sites on the order of 10^5 L or less did not penetrate to the unconfined aquifer in any significant way. Conversely, the few sites that did receive larger volumes apparently did result in aquifer contamination. Because the great majority of contaminant inventory was present in the lower volume releases, a significant vadose zone source term remains that could cause future groundwater contamination.

The technetium-99 content is of particular concern at both WMAs because of its mobility. Based on historical information, the gross beta concentrations could have been technetium-99. With the raised water table and changes in groundwater flow direction through the region, it is very difficult to assess the numerous sources for the various contaminants; however, the contribution from each SST WMA, especially at WMA C because there are no other nearby sources, must be considered.

Other current vadose zone sources are contaminated vadose sediments below the UPR-200-E-86 and UPR-200-E-81 sites and specific cribs and trenches located around WMA A-AX. It is expected that the current deployment of the surface geophysical exploration survey (see Chapter 3.0) in and around the C tank farm will provide an improved conceptual model.

Selected pages from RPP-ENV-58578, 2015, "Summary of the Natural System at Waste Management Area A/AX," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington

Figure 5-7. Hydrographs from Selected Wells in the Area of Waste Management Area A/AX, 200 East Area



its surface. Because the climate was becoming arid, the resulting soil became a pedogenically altered, carbonate-rich, cemented paleosol. The development of this carbonate-rich paleosol is much greater in the 200 West Area than in the 200 East Area due to longer exposure of the surface. This ancient paleosol is referred to as the lower Cold Creek unit (CCU_l) subunit.

Concurrently, eolian sediments and minor fine-grained flood deposits from streams originating from the nearby ridges were deposited on the paleosol, resulting in a wide variety of sediments that are called the upper subunit of the Cold Creek unit (CCU_u). Because of the long time interval (approximately 3.4 to 2 million years ago), several localized paleosols similar to the lower Cold Creek unit were able to develop in the upper Cold Creek unit. Throughout Cold Creek time, streams from the Rattlesnake, Yakima, and Umtanum Ridges were carving channels to the Cold Creek drainage area, depositing basaltic gravels in their stream beds. These form the side stream alluvial facies of the Cold Creek unit.

During Cold Creek time in the central Pasco Basin, the Columbia River flowed through Gable Gap, depositing gravels of mixed lithologies in a sand matrix. These gravels, informally called the "pre-Missoula gravels" (*Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report*, Vol. 1 [PSPL 1981]), overlie the Ringold Formation and are up to 25 m (82 ft) thick. The 200 East Area lies along the boundary between these two geologic environments, undergoing significantly more erosion than 200 West Area but with some soil development occurring in areas. There may have been other periods of fluvial deposition near the 200 East Area that reworked the existing Ringold gravels. The difficulty and uncertainty in distinguishing between these similar units is reflected in the differing choices for geologic contacts and their differing descriptions between reports.

During the Pleistocene Epoch, cataclysmic floods inundated the Pasco Basin several times when ice dams failed in northern Washington ("Quaternary Geology of the Columbia Plateau" [Baker et al. 1991]). Current interpretations suggest as many as 40 flooding events or more occurred as ice dams holding back glacial Lake Missoula repeatedly formed and broke. In addition to larger major flood episodes, there were probably numerous smaller individual flood events. Deciphering the history of cataclysmic flooding in the Pasco Basin is complicated, not only because of floods from multiple sources but also because the paths of Missoula floodwaters migrated and changed course with the advance and retreat of the Cordilleran Ice Sheet.

Along with sedimentological evidence for cataclysmic flooding in the Pasco Basin, high-water marks and faint strandlines occur along the basin margins. Temporary lakes were created when flood waters were hydraulically dammed, resulting in the formation of the short-lived Lake Lewis behind Wallula Gap. High-water mark elevations for Lake Lewis, inferred from ice-rafted erratics on ridges, range from 370 to 385 m (1,214 to 1,261 ft) above sea level.

The sediment deposited by the cataclysmic flood waters has been informally called the Hanford formation because the best exposures and most complete deposits are found on the Hanford Site. The coarse-grained flood facies (gravel-dominated facies of DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*) is generally confined to relatively narrow tracts within or near flood channels. The plane-laminated sand facies (sand-dominated facies of DOE/RL-2002-39), on the other hand, occurs as

as rising above the undifferentiated combination of CCU_l/R sediments, leaving the gravel-dominated Hanford formation sediments lying directly on top of basalt. The CCU_l/R sediments consist of predominantly sandy pebble- to cobble-sized gravel with occasional boulders. Mineralogically, the sand fraction consists of 15 to 60% basalt grains with generally less than 1 wt% calcium carbonate. The total thickness of this unit is less than 27 m (90 ft), based on a limited number of boreholes where the upper and lower boundaries are represented. The top of the undifferentiated combination of H3/CCU/R gravels ranges from about 120 to 130 m (390 to 425 ft) elevation above mean sea level.

The fine-grained unit, H3/CCU/R, is found in most boreholes beneath WMA A/AX. It occurs at a depth of about 79 m (260 ft) and ranges in thickness from 0 to 7 m (0 to 21 ft). Descriptions of this unit vary significantly, which may be due to 1) subjective descriptions and/or interpretations by different drillers and geologists; 2) heterogeneities within the unit, which may include multiple lithologic units (i.e., CCU silts overlying Ringold Formation mud); or 3) a combination of the above. Where present, this fine-grained unit is described in about half of the boreholes as a blue-, gray-, or olive-colored clay or mud; remaining borehole logs describe the unit as a tan to brown sandy silt to "heavy" silt, which may display a laminated to mottled structure. The former description fits that of Ringold Formation paleosol facies (DOE/RW-0164), whereas the latter fits descriptions for the Cold Creek silt facies (HNF-5507), interpreted as eolian-overbank in origin. Unlike most other fine-grained units in the 200 Areas, the undifferentiated Cold Creek silt and/or Ringold Formation mud unit is generally noncalcareous, containing only a few weight percent or less calcium carbonate.

Some gross gamma-ray logs show a moderate increase in activity occasionally accompanied by an increase in moisture. The water table was higher in the past; thus, the increased moisture content may be a remnant of a higher water table.

3.7.3 Hanford Formation Sediments

The Hanford formation makes up the majority of the suprabasalt sedimentary sequence beneath WMA A/AX, ranging in thickness from 61 to 83 m (200 to 275 ft). The Hanford formation has been divided into three informal units (H1, H2, and H3 from top to bottom) in the 200 East Area. These units do not correspond to similarly named units in the 200 West Area.

The H3 unit is the Hanford formation's lower gravel-dominated sequence in the area and overlies undifferentiated Cold Creek/Ringold Formation deposits. This sequence is equivalent to the lower coarse-grained unit of the Hanford formation of PNL-6820, *Hydrogeology of the 200 Areas Low-Level Burial Grounds—An Interim Report*, to the lower gravel-dominated sequence of WHC-SD-EN-TI-012, and to the Hanford formation H3 sequence of "Geohydrologic Setting of the Hanford Site, South-Central Washington" (Lindsey et al. 1994).

The H3 unit consists of clast-supported, sandy, pebble to boulder gravel to matrix-supported pebbly sand. This unit appears to be missing from beneath most of WMA A/AX. The unit is probably absent from these areas because of lateral facies changes that take place between gravel-dominated facies to the north and sand-dominated facies to the south away from the axis of primary flood channel that exists north and east of the study area. The surface of the H3 unit

5.0 GROUNDWATER SYSTEM AT WASTE MANAGEMENT AREA A/AX

This section provides a summary of the groundwater system at WMA A/AX which includes a brief description of the uppermost unconfined aquifer system including a discussion of the historic and recent groundwater data collected beneath the 200 East Area with emphasis on the A/AX Tank Farm. Most of the information in this section is derived from RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*, PNNL-15301, and RPP-RPT-46088, Rev. 1. This section also provides a summary of potential key FEPs operating within the unconfined aquifer and the associated conceptual models of groundwater flow and transport that may need to be considered in the WMA A/AX PA. Finally, this section provides recommendations for groundwater flow and transport properties that would be appropriate to use in numerical modeling of local-scale flow and transport at WMA A/AX.

Key features have been identified as potentially important to consider in conceptual models of the vadose zone at WMA A/AX and in the scope of the WMA A/AX PA calculations and related sensitivity analyses. A summary of FEPs related to the groundwater system at WMA C are presented for consideration in Appendix E of RPP-RPT-46088, Rev. 1. The FEPs are identified for two time periods: 1) the time extending from the operational period through the end of the retrieval, remediation, and correction action period and 2) future projected conditions. Due to the proximity of WMA A/AX to WMA C, these same FEPs are deemed to be applicable to WMA A/AX. The FEPs identified for past to present conditions and for projected future conditions are summarized in Tables E-1 through E-3 in Appendix E of RPP-RPT-46088, Rev 1. The key general features that were identified for the groundwater for these time periods include the following general categories.

Properties of the Major Hydrogeologic Units: The SSTs and related facilities at WMA A/AX are constructed in Hanford formation sediments, and below the water table at depth of about 80 m, these facilities are underlain by an undifferentiated unit composed of Hanford formation gravel and/or CCU (l) gravel and/or Ringold Formation, unit A referred to as the H3/CCU/R unit.

Descriptions of the general properties of the units within the unconfined aquifer beneath WMA A/AX are provided in Section 3.7 of this report and Appendix B of RPP-RPT-46088, Rev 1. All interpretations of major units along lines of section in the general area of WMA A/AX are shown in Figure B-1 of Appendix B and are provided in Figures B-1 through B-7 of RPP-RPT-46088, Rev 1.

General Flow Conditions in the Groundwater: Since the start of Hanford Site operations in the mid-1940s, artificial recharge from wastewater disposal facilities has been several times greater than the estimated recharge from natural sources. This caused an increase in the water-table elevation over most of the Hanford Site and the formation of groundwater mounds beneath major wastewater disposal facilities. In vicinity of WMA A/AX, long-term hydrographs of water-level measurements suggests that unconfined aquifer has risen as much as 5 m in response to the artificial recharge from nearby wastewater disposal facilities. More detailed discussions of regional flow in the unconfined aquifer and hydraulic impacts from past operations are provided in Sections 5.1 and 5.3.

Table 5-1 contains a list of wells near SST WMA A/AX in 200 East Area that penetrate through the entire unconfined aquifer and have 2013 water level measurements. The location of these wells is provided in Figure 5-5. Also in Table 5-1 are calculated thicknesses for the unconfined aquifer. There are very little data for WMA A/AX. The thickness of the uppermost aquifer generally increases from north to south as the top of basalt dips into the Cold Creek syncline. The unconfined aquifer beneath the SST WMAs in the 200 East Area ranges from between 0 and 7 m beneath WMA B-BX-BY which lies to the west of SST WMA C, to about 9 to 10 m beneath WMA C, to about 27 m beneath WMA A/AX.

Table 5-1. Thickness of the Unconfined Aquifer Beneath the A/AX and C Single-Shell Tanks in 200 East Area

Well Name	Well Location	Elevation of Top of Basalt[(a)] (m amsl)	Elevation of Water Table[(b)] (m amsl)	Aquifer Thickness (m)
Waste Management Area A/AX				
299-E25-2	East side of WMA A/AX	94.49	120.70	26.21
299-E24-8	~ 550 m southwest of WMA C	95.71	120.72	25.01
Waste Management Area C				
299-E26-8	~ 300 m east of WMA C	113.02	120.57	7.55
299-E27-22	North corner of WMA C	112.38	120.73	8.35

(a) Top of basalt elevation from PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*; PNNL-13023, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area A/AX at the Hanford Site*; PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*; RPP-14430, *Subsurface Conditions Description of the C and A/AX Waste Management Area*; Hanford Well Information System.

(b) July 2013 data except where noted.

amsl = above mean sea level WMA = waste management area

General groundwater flow directions and general flow rates are difficult to determine for the SST WMA A/AX due to the relatively flat water table beneath the 200 East Area (DOE/RL-2014-32). The principal vector of groundwater flow has historically been to the southeast. As the water table returns to its natural equilibrium, changes in the magnitude and direction of the hydraulic gradient are occurring. Information on the direction of flow is generally based from the examination of changes in contaminant plume movement over several years. Information on the variability/uncertainty is very limited based on the flat gradient and the small number of samples taken in any given year on contaminants of interest. Generally, the magnitude of the gradient in the area surrounding WMA A/AX is on the order of magnitude of 1E-5.

Several slug tests were done prior to 1997 in wells near 200 East Area SST farms. Table 5-2 gives the resulting hydraulic conductivity and transmissivity data from those tests. In most cases, the analyses of the data from these tests are less well documented than are more recent analyses. The original source for the data should be consulted for details of testing and analysis. The hydraulic conductivities obtained from the earlier slug test (Table 5-2) are generally lower than those measured in the more recent tests.

Selected pages from RPP-ENV-37956, 2014, "Hanford 241-A/AX Farm Leak Inventory Assessment Report," Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

3.0 BACKGROUND

Approximately 57 million gal of radioactive waste from chemical processing and plutonium processing operations are stored in 177 underground storage tanks on the Hanford Site. Of these tanks, 149 are SSTs, which consist of a single steel liner inside a reinforced concrete tank. Nominal capacities range from 55,000 to 1,000,000 gal. For the immediate future, plans call for retrieval of waste from the SSTs and transfer to the 28 double-shell tanks (DSTs) with proven integrity, and eventual transfer for treatment in the Waste Treatment and Immobilization Plant.

3.1 241-A AND 241-AX TANK FARMS DESCRIPTION

The 241-A Tank Farm was constructed between 1954 and 1955. The SSTs in A Farm were operated as boiling waste tanks. The heat generated from the decay of radionuclides was sufficient to result in the evaporation of water from the wastes stored in these tanks. The water vapor and other off-gases from the A Farm SSTs were drawn from each tank through an underground 20-in.-diameter pipe that connects to an underground 24-in.-diameter pipe (i.e., vapor header). When AX Farm was constructed in 1963 and 1964, a similar vapor header was installed for these four SSTs. An underground 20-in.-diameter pipe connects from each SST to an underground 24-in.-diameter pipe. The underground 24-in.-diameter pipe runs to the 241-AX-152 diverter station. From the 241-AX-152 diverter station, the underground 24-in.-diameter pipe from the 241-AX vapor header connects to the A Farm vapor header.

The A Farm vapor header connects to underground condensers and de-entrainment vessels and then enters the 241-A-431 fan house and de-entrainment building. The 241-A and 241-AX Tank Farm Process Condensate (TFPC) was removed from the A and AX Farm off-gases and collected in tank 241-A-417. The off-gas was filtered and discharged through an exhaust stack. Initially, the condensate collected in tank 241-A-417 was either returned to one of the A or AX Farm SSTs or discharged to a crib. In January 1970, a prototype ion exchange system was installed to remove ^{137}Cs from the TFPC prior to discharge to cribs (PR-REPORT-JAN70, *Monthly Status & Progress Report January 1970*, pp. AV-2). Table 3-1 summarizes the analyses of the untreated TFPC waste located in reference documentation. The composition of the Plutonium Uranium Extraction (PUREX) high-level waste (HLW) supernate in tanks 241-A-101 (A-101), 241-A-104 (A-104), and 241-A-106 (A-106) in September 1964 are provided in Table 3-2 (RL-SEP-183-RD, *PUREX Tank Farm Supernatant Solution Composition*). In comparison with the TFPC, the ^{137}Cs concentration in the PUREX HLW supernate was ~100,000 times higher.

While not reported in these analyses, ^{60}Co was present in relatively small concentrations in the TFPC waste. The 216-A-8 crib received the TFPC waste from November 1955 through May 1956 and from April 1966 through April 1971. The 216-A-8 crib also received process condensate from 241-AY Tank Farm after April 1971. The 216-A-24 crib received TFPC waste from May 1956 through April 1966.

- RPP-25113, *Residual Waste Inventories in the Plugged and Abandoned Pipelines at the Hanford Site*
- RPP-RPT-29191, *Supplemental Information Hanford Tank Waste Leaks*
- Waste status summary and monthly report for the Hanford site from January 1945 through December 1980 (various reports)
- RHO-CD-673, *Handbook 200 Areas Waste Sites*
- Historical Occurrence Reports.

Table 5-2 identifies documented known or suspected UPRs in A and AX Farms. The date the release was detected, the waste type and the volume of waste released to the soil (if known) are listed in Table 5-2. Some, but not all of these releases are designated UPRs in the Waste Information Data System (WIDS) database. Releases not currently included in WIDS will be submitted to the WIDS coordinator. Figures 5-2 to 5-5 show pipelines in the A and AX Farms and identify the location of some of the releases described in Table 5-2.

Except as noted, information available was insufficient to estimate a release volume or inventory for pipeline failures and surface releases. In some cases, failed pipelines were contained within a concrete diversion box, vault, or pipeline encasement. The surfaces of these concrete structures were coated with a chemically resistant paint. However, the integrity of the coatings and concrete structures are unknown and it is not known whether waste was released from these concrete structures. Additional near-surface data needs will be determined through data quality objective workshops in support of WMA A-AX performance assessments and corrective management studies.

5.3 OTHER POTENTIAL LOSSES

Unplanned releases in Table 5-2 are those for which documented information was available. Other UPRs likely occurred that were not documented or for which information is not available.

A 1984 BWIP water balance study (Internal letter 65633-128, "Status of the BWIP Water Balance Study") showed that between 1977 and 1984, between 15% and 41% (24% average) of the 8E9 L of water discharged to East Area general raw water lines was unaccounted for, suggesting either error in process measurements or significant losses in the water lines. While raw water losses do not increase the inventory of waste lost to the soil, they provide a substantial driving force to move mobile contaminants toward groundwater. Although raw water lines and waste process lines are constructed to different specifications, these raw water loss estimates give an indication of other potential losses from waste process lines.

B3.0 TANK 241-A-105

This section provides information on the historical waste loss event associated with tank A-105. Waste operations for tank A-105 are summarized in Figure B3-1. Figure 3-2 of the main text shows a plan view of a typical tank in A Farm with the location of the pump pit, sluice pit, spare inlet nozzles (N1-N5) and tank risers.

B3.1 TANK 241-A-105 WASTE HISTORY

The operational history for tank A-105 is summarized from 7G420-06-004 – Interoffice memorandum, 7G420-06-005 – Interoffice memorandum, and DOE/ORP-2008-01, *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas*.

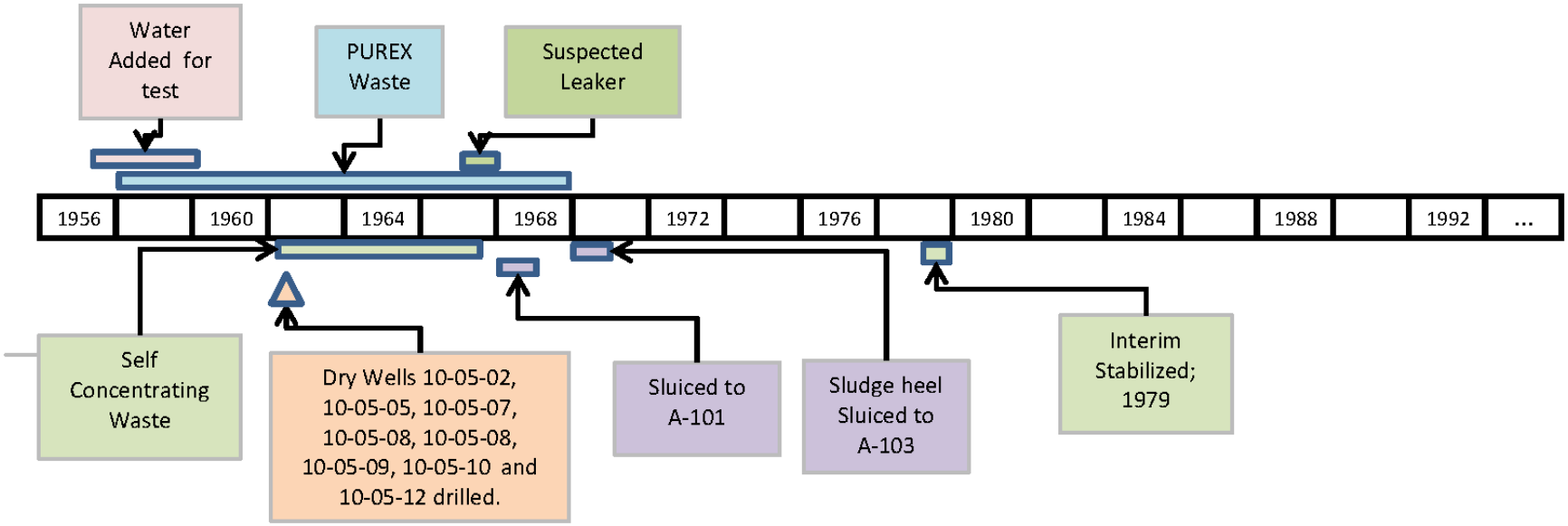
Tank A-105 initially sat unused from finish of construction until May 1962. Aged[3] PUREX HLW supernate was first added to this tank from tank A-103 in May 1962. Additional aged PUREX HLW supernate was added to tank A-105 from tank A-102 in December 1962. Then the contents of tank A-105 were pumped to tanks 241-C-103 and A-101 in January 1963, leaving a 10-in. (~27,600-gal) heel of waste in tank A-105. Thermally hot condensate was added to tank A-105 to heat the tank in preparation to receive HLW from the 202-A PUREX Plant.

Beginning in February 1963, tank A-105 began to receive HLW directly from the 202-A PUREX Plant. The PUREX HLW contained significant concentrations of fission products that resulted in the waste self-boiling. As space became available in tank A-105 as a result of waste evaporation, periodic transfers of PUREX HLW were received until January 1965, at which time it contained 866,000 gal of waste. The maximum reported waste temperature in tank A-105 was ~320 °F in March 1963, but generally was controlled to 180 °F to 260 °F from February 1963 through March 1965 (RHO-CD-1172, pp. B-39 through B-45). On November 19, 1963, there are indications that this tank developed a small leak due to radioactivity detected in lateral 14-05-03 (ARH-78). Additional waste was released from this tank during a steam expulsion event that occurred on January 28, 1965 (ARH-78).

On January 28, 1965, tank A-105 experienced a rapid pressurization event that resulted in the tank liner bulging upward. Radioactivity (250,000 to 350,000 cpm) was detected in March 1965 in a small area of lateral no. 3 beneath the tank. The activity detected in lateral no. 3 did not significantly change from March 1965 through January 1968. The tank liquid level was maintained between 850,000 and 887,000 gal through January 1968 by addition of water. As discussed in WHC-MR-0264, *Tank 241-A-105 Leak Assessment*, radioactivity was also detected in lateral no. 2 beneath tank A-105 in October 1967.

[3] The term "aged" means the short half-life radionuclides had decayed sufficiently that the waste was no longer self-boiling.

Figure B3-1. Tank 241-A-105 Waste Operations Summary



PUREX = Plutonium Uranium Extraction (Plant)

From February 1968 through August 1968, the supernate in tank A-105 was removed and the supernate heel diluted through a series of flushes using B Plant cesium ion exchange supernate (waste type CSR as defined in RPP-26744, *Hanford Soil Inventory Model, Rev. 1*) in preparation for sluicing the sludge in this tank (7G420-06-004 – Interoffice memorandum). The ^{137}Cs concentration in the CSR supernate used to flush the HLW supernate in tank A-105 was an average of 0.58 Ci/gal, decay corrected to January 2006 (7G420-06-004 – Interoffice memorandum). The tank A-105 flush solution was transferred to tank A-103, then tank AX-102 and finally to B Plant for cesium removal processing.

Following the dilution and flushing of tank A-105 supernate, two sluicing campaigns were conducted to remove the sludge from tank A-105. The first sluicing campaign, conducted from August through November 1968, used cesium denuded supernate derived from operation of the cesium ion exchange process in B Plant (7G420-06-004 – Interoffice memorandum). The ^{137}Cs concentration of the sluicing fluid was estimated to be 0.53 Ci/gal to 0.58 Ci/gal (decay corrected to January 2006). Sluicing of tank A-105 sludge was halted when little of the remaining sludge could be removed. A hard crust layer atop the remaining sludge was thought to be responsible for preventing effective sluicing. Approximately half of the sludge was removed during this first sluicing campaign.

In the second sluicing campaign, 1M sulfuric acid, containing 1,500 ppm of the inhibitor Rhodine A[4], were sprayed onto the top layer of hard sludge in tank A-105 (7G420-06-005 – Interoffice memorandum). Cesium denuded supernate, generated in B Plant and contained in tank A-103, was used as the sluicing fluid. The sludge sluiced from tank A-105 was transferred into tank A-103. No additional sludge removal activities in tank A-105 were conducted until August 25, 1970. Inhibited sulfuric acid was again used in August 25, 1970 to soften the sludge in tank A-105. The softened sludge was then sluiced using cesium denuded supernate contained in tank A-103. The sludge slurry was transferred from tank A-105 to tank A-103. Following the completion of this phase of the sludge removal from tank A-105, ~33,000 gal of supernate and 33,000 gal of sludge were reported to remain within this tank. The supernate contained in tank A-105 was described as being a mixture of B Plant cesium ion exchange waste (i.e., cesium denuded ion exchange waste) and PUREX HLW.

The cesium denuded supernate used to sluice the sludge from tank A-105 to tank A-103 was derived from cesium ion exchange processing conducted in B Plant. Sluicing conducted in July to August 1969 used the same cesium denuded supernatant solution as was used during the first tank A-105 sluicing campaign. However, tank A-105 sluicing conducted in August to November 1970 used a different source of cesium denuded supernate. The estimated concentration of the cesium denuded supernate used to conduct sluicing of tank A-105 sludge to tank A-103 from August to November 1970 is 0.51 Ci/gal, decayed to January 2006 (7G420-06-005 – Interoffice memorandum).

Following the sluicing of the waste, water was periodically added to tank A-105 from November 1970 through December 1978 for evaporative cooling of the remaining sludge. An estimated 610,000 gal of water was added to tank A-105 for cooling and flushing of the airlift

[4] Trade name of Amchem Products Corporation.

circulators (WHC-MR-0264, pp. 22). The estimated amount of water evaporated from tank A-105 from November 1970 through December 1978 is 378,000 to 410,000 gal (WHC-EP-0410, *Tank 241-A-105 Evaporation Estimate 1970 through 1978*). Therefore, an estimated 200,000 to 232,000 gal of water are unaccounted for and may have leaked from tank A-105.

Figure B3-2 shows quarterly tank transfer levels and history. Additional tank waste transfer information is included in WHC-MR-0132, LA-UR-97-311 and tank waste summary reports.

B3.2 INTEGRITY OF TANK 241-A-105

Tank A-105 is designated a confirmed leaker with an estimated loss of liquid attributed to a breach in tank liner integrity at 10,000 to 270,000 gal (HNF-EP-0182). The leak volume range for tank A-105 (10,000 to 277,000 gal) is based on the following.

a. WHC-MR-0264:

   An estimate of 5,000 to 15,000 gal for the initial leak prior to August 1968.

   An estimate of 5,000 to 30,000 gal for the leak while the tank was being sluiced from August 1968 to November 1970.

   An estimate of 610,000 gal of cooling water was added to the tank from November 1970 to December 1978, but it was estimated that the release from the tank was likely small during this period. "Sufficient heat was generated in the tank to evaporate most, and perhaps nearly all, of this water" (WHC-MR-0264). This result leads to an estimate of no gallons released from the tank during the period of November 1970 to December 1978.

b. WHC-EP-0410 estimates that 378,000 to 410,000 gal evaporated out of the tank from November 1970 to December 1978. Subtracting the minimum evaporation estimate from the cooling water added estimate provides a range from 0 to 232,000 gal of cooling water leakage from November 1970 to December 1978.

In 1977, photographs taken inside tank A-105 in 1969, 1970, and 1977 were reviewed to determine the amount of sludge remaining in the tank as well as develop a topographical map of the tank bottom (WCC Project 1397A-0300, *An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford, Washington*). The topographical map of the tank bottom produced in 1977 is shown in Figure B3-3. This topographical map shows the bottom of the steel liner in tank A-105 is ripped and separated from the sidewall along approximately 3/4 of the tank bottom.

Selected pages from RPP-RPT-58867, 2015, "AX Farm Groundwater Risk Constituent Concentration Determination," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

3.0 RESULTS

The results for constituents of concern are summarized in tables 3-1 through 3-4. Full water wash plots from the Stream Analyzer model can be found in the appendix. The maximum concentrations shown in the tables should be used in the groundwater model for risk.

Table 3-1. AX-101 Maximum Concentrations

Constituents of Concern	Maximum Concentration*	Units	Ci/L or g/L
Tc-99	1.27E-04	moles/L	2.13E-04
I-129	9.68E-06	moles/L	2.20E-07
U	1,220	mg/L	1.22
Cr	4,510	mg/L	4.51
NO2	121,000	mg/L	121
NO3	247,000	mg/L	247

Tc-99 Conversion: Conc x 99 g/mole x 1.695E-02 Ci/g

I-129 Conversion: Conc x 129 g/mole x 1.765E-04 Ci/g

*Maximum concentration in first 10,000 gallons of sluice water.

Table 3-2. AX-102 Maximum Concentrations

Constituents of Concern	Maximum Concentration	Units	Ci/L or g/L
Tc-99	2.55E-05	moles/L	4.28E-05
I-129	5.08E-06	moles/L	1.16E-07
U	3,650	mg/L	3.65
Cr	690	mg/L	0.69
NO2	30,900	mg/L	30.9
NO3	157,000	mg/L	157

Tc-99 Conversion: Conc x 99 g/mole x 1.695E-02 Ci/g

I-129 Conversion: Conc x 129 g/mole x 1.765E-04 Ci/g

*Maximum concentration in first 10,000 gallons of sluice water.

Table 3-3. AX-103 Maximum Concentrations

Constituents of Concern	Maximum Concentration	Units	Ci/L or g/L
Tc-99	9.54E-05	moles/L	1.60E-04
I-129	6.88E-06	moles/L	1.57E-07
U	440	mg/L	0.44
Cr	4,840	mg/L	4.84
NO2	123,000	mg/L	123
NO3	156,000	mg/L	156

Tc-99 Conversion: Conc x 99 g/mole x 1.695E-02 Ci/g

I-129 Conversion: Conc x 129 g/mole x 1.765E-04 Ci/g

*Maximum concentration in first 10,000 gallons of sluice water.

Table 3-4. AX-104 Maximum Concentrations

Constituents of Concern	Maximum Concentration	Units	Ci/L or g/L
Tc-99	1.87E-04	moles/L	3.14E-04
I-129	2.49E-07	moles/L	5.67E-09
U	2,520	mg/L	2.52
Cr	444	mg/L	0.444
NO2	1,720	mg/L	1.72
NO3	35,000	mg/L	35

Tc-99 Conversion: Conc x 99 g/mole x 1.695E-02 Ci/g

I-129 Conversion: Conc x 129 g/mole x 1.765E-04 Ci/g

*Maximum concentration in first 10,000 gallons of sluice water.

Selected pages from Schwarzenbach, René P., Philip M. Gschwend, and Dieter M. Imboden, 1993, Environmental Organic Chemistry, John Wiley & Sons, Inc., New York, New York.

For comparison, we note that $m/\rho_{\text{liquid}} = 90.3\ \text{cm}^3\cdot\text{mol}^{-1}$. Using this result in Eq. 9-26 we obtain

$$D_w(\text{trichloroethylene}) = \frac{13.26 \times 10^{-5}}{(0.894)^{1.14}(93.5)^{0.589}}\ \text{cm}^2\cdot\text{s}^{-1} = 1.04 \times 10^{-5}\ \text{cm}^2\cdot\text{s}^{-1} \tag{9-28}$$

Generally, this approach also yields results that are correct to within 10%.

In light of our intuition, as well as the semiempirical equation given above, it should come as no surprise that solution phase diffusivities can also be estimated by comparison to known results for related compounds. Given the Othmer and Thaker equation (Eq. 9-26), one expects

$$\frac{D_w(\text{unknown})}{D_w(\text{known})} \simeq \left(\frac{\text{diffusion volume}_{\text{known}}}{\text{diffusion volume}_{\text{unknown}}}\right)^{0.589} \tag{9-29}$$

and this compares favorably with what we saw in the data plotted in Figure 9.7.

Again, molecular masses are widely used as relative indices of molecular size, and a square-root functionality is used for simplicity:

$$\frac{D_w(\text{unknown})}{D_w(\text{known})} \simeq \left(\frac{m_{\text{known}}}{m_{\text{unknown}}}\right)^{0.5} \tag{9-30}$$

Figure 9.7*b* indicates that within a class of molecules like benzene derivatives, the inverse relationship of diffusivity to molecular mass is clear.

In summary, reasonably accurate means exist for estimating gas phase and solution diffusivities of organic chemicals of interest. Generally, only some knowledge of chemical size is needed (e.g., diffusion volume, or more approximately, molecular mass) to obtain estimates within 10% of measured results.

9.4 TURBULENT DIFFUSION

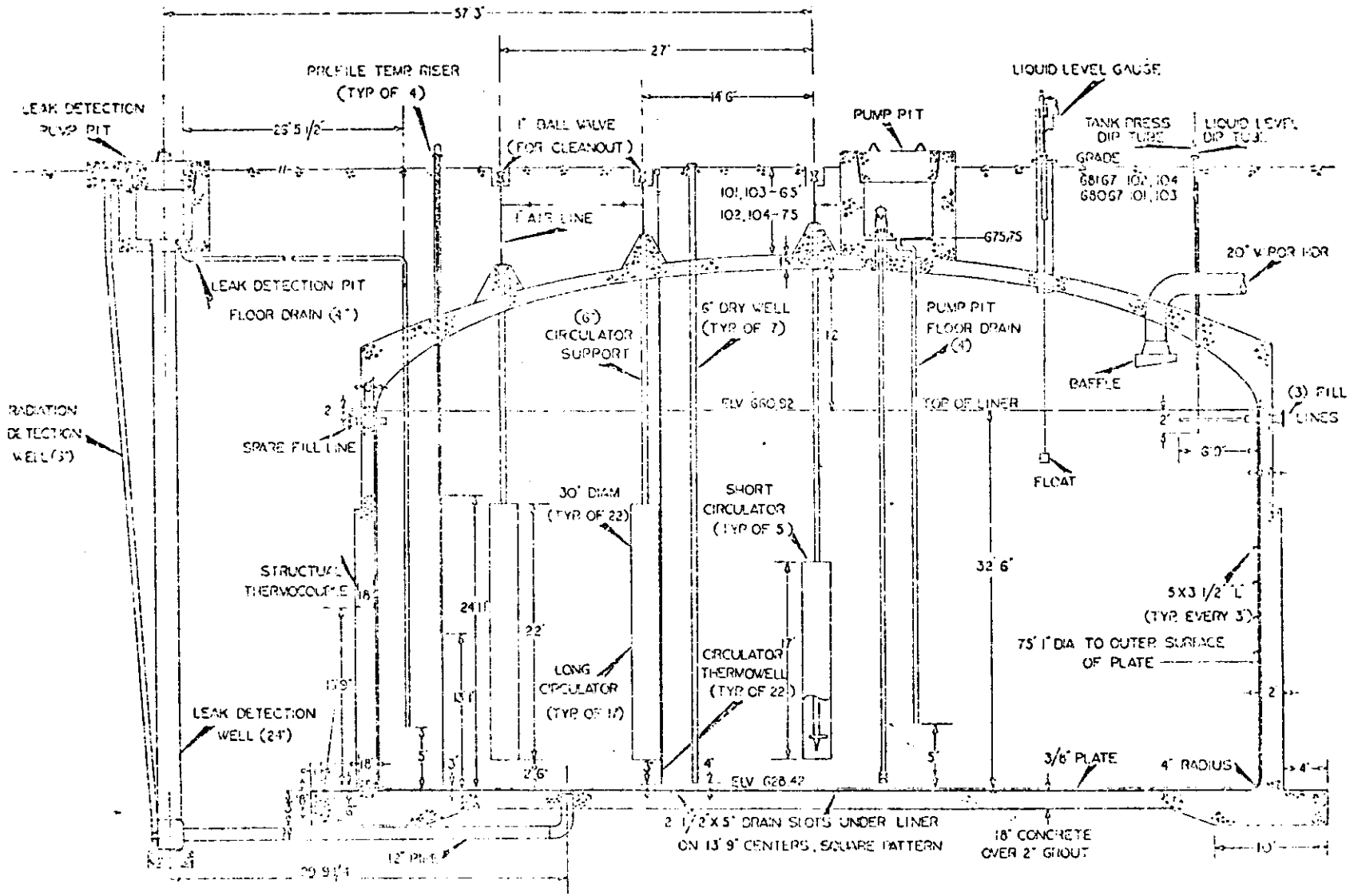
Molecular diffusion is important mainly on the microscopic scale. It brings reactants into contact with each other and transports chemicals across boundaries, for example, into a living cell, onto a particle surface, or across the air–water interface (see Chapter 10). Yet on a macroscopic scale—that of rivers, lakes, or subsurface aquifers—molecular diffusion is extremely slow. From Eq. 9-9 we can calculate the characteristic transport time t_d to diffuse the distance L:

$$t_d = \frac{L^2}{2D} \tag{9-31}$$

Selected pages from SD-WM-TI-356, 1988, "Waste Storage Tank Status and Leak Detection Criteria," Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Rev. 0

COMPOSITE SECTION – AX FARM TANK



SD-WM-TI-356
11-00-01

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ATTACHMENT 4

SOFTWARE INSTALLATION AND CHECKOUT FORM

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: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 4

EXECUTABLE INFORMATION:

2. Executable Name (include path):

All executable files installed in directory /srv/samba/saved_data/bin

MD5 File Signature	Executable File Name
6536b8e12d8c5b83dca76f2c947b6153	stomp-wae-bcg-chprc04i.x
e0cdf04bc1a2f6c55c5a1b499939f663	stomp-wae-bcg-chprc04l.x
6e72340bb39f6056e232fe5ff241c4d4	stomp-wae-bd-chprc04i.x
3f837a0fb8d9f47dbcada686f542d7fc	stomp-wae-bd-chprc04l.x
7e5b4cc36a8991b3d5a8ea2ed155ce47	stomp-wae-cgsq-chprc04i.x
00a898c0c3ec06817485781ad1c9ec46	stomp-wae-cgsq-chprc04l.x
f18ff5ab5667065d8ab12657344fb6a0	stomp-wae-cgst-chprc04i.x
061af86cf21ad8435b046d0efabe971b	stomp-wae-cgst-chprc04l.x
3c8111a9855dc0e430bf3c8a7abcf37e	stomp-w-bcg-chprc04i.x
20436d615a94955a2ce8eecdb8cba546	stomp-w-bcg-chprc04l.x
8b3df29df21d040189c3e2a50ef823bb	stomp-w-bd-chprc04i.x
066a289a75aedb933eb2536da5d7d1ff	stomp-w-bd-chprc04l.x
c8e62ad7a0d9b6fca39d8a8952ef5d8e	stomp-w-cgsq-chprc04i.x
28ad16806e1307aca51fd7bf89793e75	stomp-w-cgsq-chprc04l.x
6c25051016db2fe1f883a7caaaab1e97	stomp-w-cgst-chprc04i.x
ff9ff6f29b3469419ffaece87d7e772b	stomp-w-cgst-chprc04l.x
0c3e3fba40f5b93e71bcf9586432fd27	stomp-w-r-bcg-chprc04i.x
78492aee80a8c2d0a4e82aabf4a9c213	stomp-w-r-bcg-chprc04l.x
84b129786aba9c4be884e15e45a67389	stomp-w-r-bd-chprc04i.x
e990f1566c8099a8d54508de3da9cd88	stomp-w-r-bd-chprc04l.x
18a589a2b55aab2db290efea19b39351	stomp-w-r-cgsq-chprc04i.x
6569959476772a137df35ce874821889	stomp-w-r-cgsq-chprc04l.x

3. Executable Size (bytes): MD5 signatures above uniquely identify each executable file

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

Tellus Subsurface Modeling Platform

5. Operating System (include version number):

Linux tellusmgmt.rl.gov 2.6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86 64 x86 64 GNU/Linux

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

Green Linux Cluster

7. Operating System (include version number):

Linux green 3.2.0-35-generic #55-Ubuntu SMP Wed Dec 5 17:42:16 UTC 2012 x86_64 x86_64 x86 64 GNU/Linux

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 4

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

/srv/samba/saved data/test/stomp/build-04/itc

10. Procedure(s):

CHPRC-00211 Rev 1, STOMP Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

Input files for ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-2
(Baseline for comparison are results files from ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-3 prepared on Tellus during acceptance testing)

13. Output Files:

plot.* files produced by STOMP in testing

14. Test Cases:

ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-3

15. Test Case Results:

Pass for all executable files listed above.

16. Test Performed By: WE Nichols

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Accepted; Installation noted in HISI for users TJ Budge, N Hasan, A Mayenna, WJ McMahon, WE Nichols, S Mehta, H Rashid.

Prepared By:

19. Software Owner (Signature)	WE Nichols Print	25 APRIL 2013 Date

20. Test Personnel:

Sign	WE Nichols Print	25 APRIL 2013 Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21. Software SME (Signature)	N/R (per CHPRC-00211 Rev 1) Print	Date

Att-4-3

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