ECF-200UP1-17-0011
Revision 0

200-UP-1 Telescopic Mesh Refinement Model, Uranium Plume Capture, and Additional Extraction Well Location Analysis

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

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ENVIRONMENTAL CALCULATION COVER PAGE

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Checker:	JP McDonald / Sr. Hydrogeologist	[signature]	2/21/2017
Senior Reviewer:	G Ruskauff / Pr. Hydrogeologist	[signature]	2/21/2017
Responsible Manager:	AH Aly/Risk & Model Intergrat. Mngr	[signature]	2/23/17

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PRIOR TO INITIATING MODELING:

Required training for modelers completed:

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Safety Software Approved:

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Basis of Qualifications for ECF Roles

Preparer: John Ewing

Senior Water Resources Engineer

MS, Civil Engineering, University of Colorado, 1996

BS, Civil Engineering, University of Colorado, 1993

Licenses: Professional Engineer (Texas)

John Ewing's experience has focused on the development, calibration, and application of numerical models of single- and multi-phase fluid flow and transport in the subsurface. He uses models to address a variety of water resource management, radioactive waste isolation, and environmental investigation and remediation issues. Working for federal and state agencies responsible for the management, preservation, and protection of water resources, his experience includes developing regional-scale groundwater availability models (GAMs) of aquifers to support long-term planning and aquifer management. He has also used more local-scale models to help locate and design water supply wells and evaluate the impacts of groundwater pumping in the context of major water development and delivery projects. John has applied his modeling expertise to support national programs in the US, Switzerland, and France established to safely dispose of low-, intermediate-, and high-level radioactive wastes in deep geologic repositories. In support of site characterization and suitability evaluations, repository performance and safety assessments, and facility licensing, he has developed and applied process and system models to evaluate issues such as heat and gas evolution resulting from the storage of wastes and the performance of engineered barrier systems (EBS) designed to isolate wastes within a repository. As part of environmental protection and restoration activities at US Department of Energy, US Department of Defense, federal Superfund, and commercial mining operations and petroleum refining plants, John has used models to determine the nature, extent, and migration of subsurface contaminants, evaluate the feasibility of various remedial alternatives, define regulatory boundaries, design monitor well networks, and design and optimize remedial systems that include injection/extraction well systems for surfactant floods, soil vapor extraction systems, and interceptor trenches. His work has addressed soils and groundwater contaminated by chlorinated solvents, petroleum hydrocarbons, metals, and radionuclides. John has experience applying a variety of public domain and proprietary modeling codes that include the MODFLOW suite of codes, TOUGH, FEHM, UTCHEM, MUFTE UG, SWIFT II, UTSTREAM, IHM, and SWAT and he is an expert in applying automated calibration codes including PEST, ITOUGH, and UCODE, and in running models and conducting sensitivity and uncertainty analyses on computing clusters using parallelization software.

Checker: John McDonald

Hydrologist

BS, Geology, Eastern Washington University, 1993

AS, General Studies, Columbia Basin College, 1989

AAS, Computer Science, Columbia Basin College, 1985

John McDonald brings experience in soil and groundwater remediation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA). He specializes in groundwater sampling, water-level monitoring, groundwater sample representativeness, hydraulic gradient determinations by trend-surface analyses, flow dynamics in high transmissivity aquifers, barometric corrections by multiple regression/deconvolution, analyses of automated water-level data, hydrologic testing data analysis, and statistical analyses. His experience includes implementation of remedial actions, conceptual model development, multimedia/risk assessment modeling, groundwater sample data interpretation, water level data interpretation, and reporting. He also has experience in taking hydraulic head measurements, operating continuous water-level recording equipment, generating potentiometric surface maps, conducting hydrologic tests, collecting water samples, and generating contaminant plume maps.

Senior Reviewer: Greg Ruskauff

Principal Engineer

MS, Petroleum Engineering, New Mexico Institute of Mining and Technology, 1985

BS, Petroleum Engineering, New Mexico Institute of Mining and Technology, 1983

Greg Ruskauff's professional experience has focused on the areas of performance assessment of both near-surface and geological radioactive waste repositories, regulatory development, dose assessment for residual contamination of soils and buildings, toxic materials risk assessment, and mixed waste issues. His experience includes performing, planning, and managing site investigations and groundwater modeling on various types of projects. He brings expertise in coordinating teams of technical experts to perform activities necessary for the development of integrated interpretations of complex groundwater systems in order to meet or exceed regulatory-driven requirements. He led the analysis and modeling team for a large federal environmental restoration site, whose primary task was to characterize the complex subsurface environment and evaluate groundwater contamination from historical underground nuclear testing. Under Greg's leadership the activity passed, for the first time, a public peer review required by the regulatory agency advancing the first corrective action unit out of characterization and toward closure. The organizational approach was judged to be so successful that the preparation for the next peer review followed the same pattern. Greg's career has been marked by numerous promotions on important federal projects due to his reliable technical and regulatory leadership skills.

Environmental Calculation File

Local-Scale Simulation of Uranium Plume Capture at the 200-UP-1 Uranium Pump-and-Treat Well Locations

Contents

Figures

Tables

Terms

amsl	above mean sea level
AWLN	Automated Water Level Network
CHPRC	CH2M HILL Plateau Remediation Company
CPGW Model	Central Plateau Groundwater Model
DOE	U.S. Department of Energy
ECF	environmental calculation file
HISI	Hanford Information System Inventory (database)
HSU	hydrostratigraphic unit
MCL	maximum contaminant level
MODFLOW	MODular three-dimensional finite-difference groundwater FLOW model (software)
MODPATH	particle tracking post processing code for MODFLOW (software)
SALDS	State Approved Land Disposal Site (facility)

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1 Purpose

The purpose of this environmental calculation file (ECF) is to document and present the results of hydraulic capture modeling performed using a local-scale submodel derived from the Central Plateau Groundwater Model (CPGW Model) Version 8.3.4 and implemented in the CH2M HILL Plateau Remediation Company (CHPRC) versions of MODFLOW-2000. The results of this model are intended to support the capture zone analysis of the uranium plume from the 216-U-1 and 216-U-2 Cribs near the U Plant at the US Department of Energy's (DOE's) Hanford Site shown in Figure 1. U Plant is in the 200 West Area of the Hanford Site; a more detailed map of this location is shown in Figure 2. This environmental calculation brief represents an update to the prior refined model simulations presented in ECF-200UP1-14-0032, *Local-Scale Simulation of Uranium Plume Capture at the 200-UP-1 Uranium Pump-and-Treat Well Locations*.

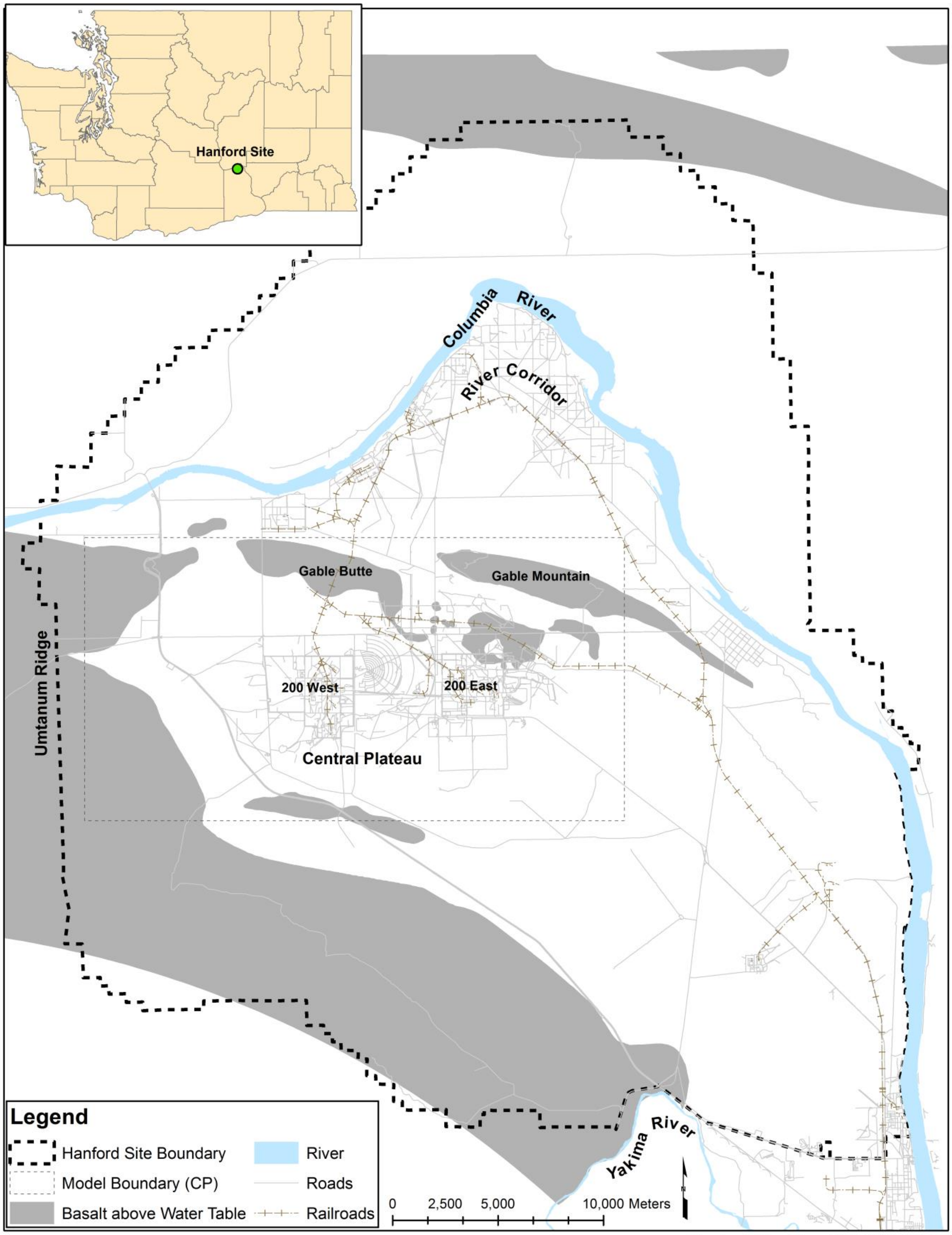

Figure 1. Hanford Site Map

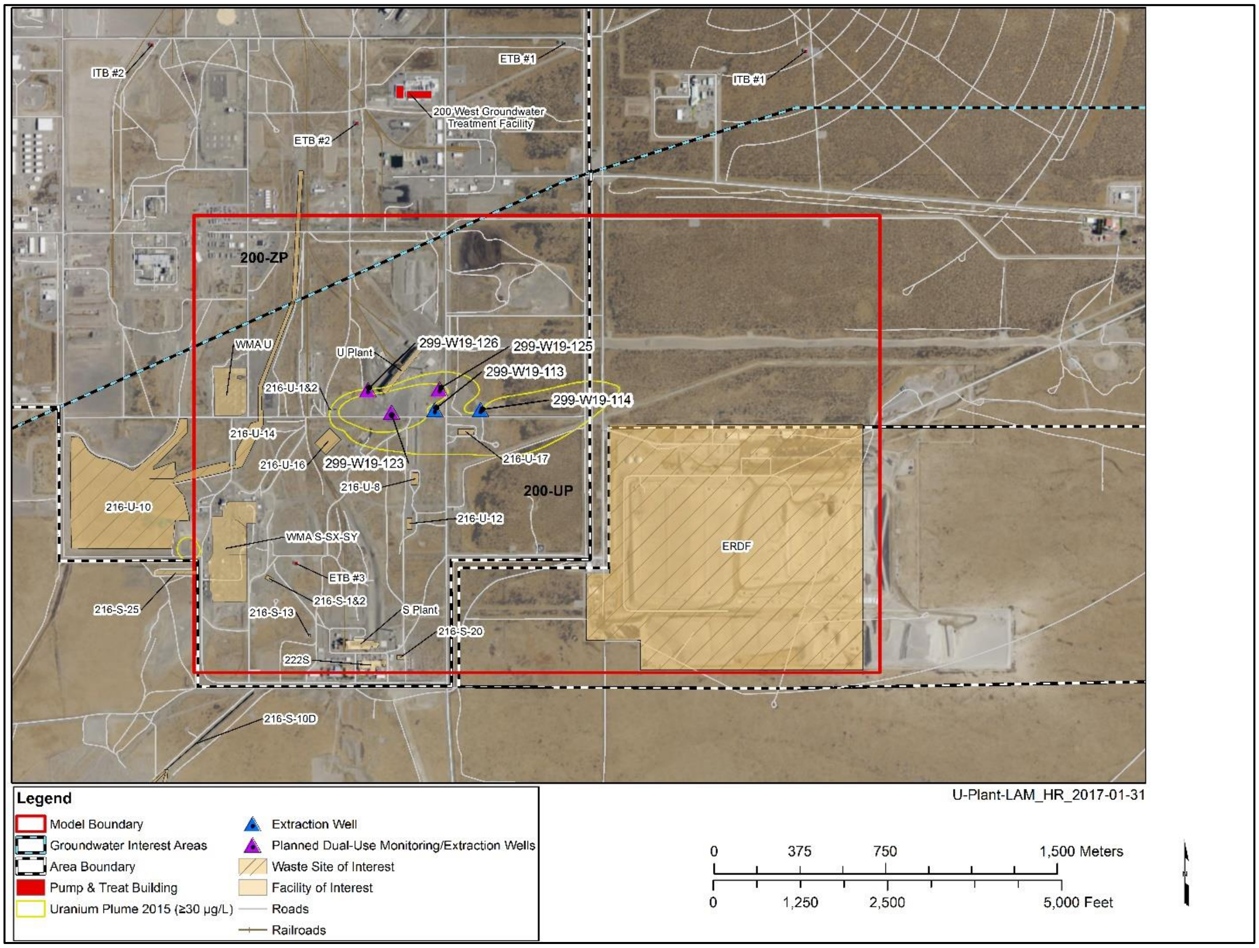

Figure 2. U Plant Vicinity Map

2 Background

The 216-U-1 and 216-U-2 Cribs were active in the 1950s and 1960s and received waste from uranium recovery operations at U Plant. The cribs received an estimated 4,000 kilograms of uranium during this time (DOE/RL-2009-122, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*). When wastewater was disposed at the nearby 216-U-16 Crib (Figure 2) in the mid-1980s, it migrated north along a caliche layer and mobilized the technetium-99 and uranium in the vadose zone soil column beneath the 216-U-1 and 216-U-2 Cribs, which added contaminant mass to the groundwater plume (WHC-EP-0133, *U1/U2 Uranium Plume Characterization, Remedial Action Review and Recommendation for Future Action*; PNL-8073, *Hanford Site Ground-Water Monitoring for 1990*). A pump-and-treat system operated in the central portion of this plume from 1994 until 2011, and during this time, 220.5 kilograms of uranium were removed from the aquifer.

The objective of the current remedial action is to continue to reduce uranium concentrations in the aquifer to below the maximum contaminant level (MCL) and contain the source area at the 216-U-1 and 216-U-2 Cribs. The results of the model provide estimates of the area of the plume captured and contained by several alternative pump-and-treat system scenarios.

The scope of this calculation is limited to hydraulic capture analysis. Simulation of contaminant transport of the local plume associated with U Plant is excluded from this scope. The predictive modeling timeframe begins in calendar year 2016 and continues for 25 years to demonstrate capture performance.

Injection of treated groundwater into the aquifer occurs in the 200-ZP-1 groundwater operable unit injection wells, which are located outside of the model domain. Artificial recharge occurs at the State Approved Land Disposal Site (SALDS), which is located north of the 200 West Area boundary outside of the model domain.

The remedial action will be utilizing two or three extraction wells. Two extraction wells are currently operating and three dual-use monitoring/extraction wells are either being planned or are currently being drilled. The location, screen interval, and historical pumping rates of the two existing extraction wells are based on surveyed locations and flow measurements. A predictive scenario, based on the two existing extraction wells pumping at rates of autumn 2016, has been simulated. Alternative predictive pumping scenarios have been simulated using various combinations of the existing and prospective extraction wells pumping at different rates to inform an optimal pumping scenario.

3 Methodology

The U Plant Submodel was constructed as follows:

1. The CPGW Model was used as the base model.
2. The submodel domain, finite-difference grid and hydraulic properties were taken from the submodel reported in ECF-200UP1-14-0032 (Figure 3).
3. The resulting head values from version 8.3.4 of the CPGW Model (extended to 2040) were used to calculate the time-varying constant head boundary values at the perimeter of the submodel.
4. MODFLOW datasets for the new submodel were created, and a forward-run was performed.
5. Drawdown at the Automated Water Level Network (AWLN) wells, which measured water levels prior to and following pumping from the existing extraction wells, were compared to simulated drawdown between 2015 and 2016.
6. The simulated magnitude and direction of the hydraulic gradient was compared to the observed values south of the extraction wells prior to and following the onset of pumping from the extraction wells.

Once the U Plant Groundwater Submodel was developed, it was available for use to calculate hydraulic capture zones. The MODPATH software was used to calculate reverse particle tracks associated with the extraction wells for each of the potential extraction scenarios. The particle tracks identify the area within the aquifer captured by the extraction wells as a function of time from commencement of pumping. No adsorption is considered so each particle represents a parcel of water moving with the groundwater velocity.

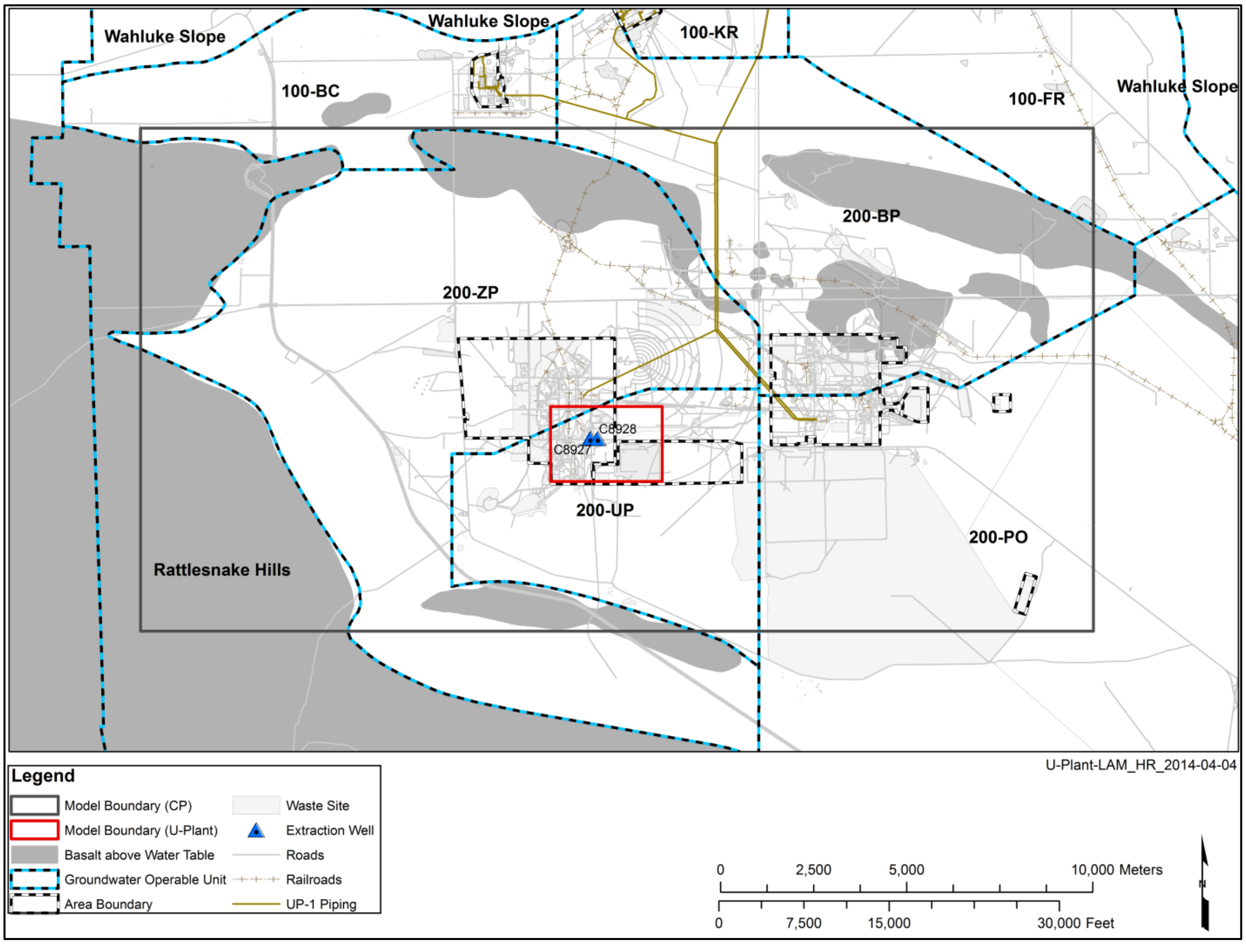

Figure 3. Central Plateau Groundwater Model Version 8.3.4 Domain and Coincident U Plant Submodel Domain

4 Assumptions and Inputs

Assumptions and inputs applicable to this ECF are presented in this section.

4.1 Submodel Domain

The submodel domain extends 3,000 meters west to east and 2,000 meters south to north, and is located as shown in Figure 2. This area represents the maximum areal extent, with some added buffer, to which the optimized extraction rates associated with the UP-1 Uranium Remedy-Remedial Design affected the results of the CPGW Model in ECF-200UP1-14-0031, *Optimization of 200-UP-1 Uranium Pump-and-Treat Well Locations with Resultant Contaminant Effluent Concentrations* (i.e., the submodel boundary is not impacted by the uranium extraction wells).

The local grid was refined from the extracted portion of the CPGW Model to provide suitable resolution for simulating details of hydraulic capture near the targeted uranium plume. The CPGW Model is discretized with a grid spacing of 100 by 100 m, and 7 layers. The U Plant Submodel was refined to 2 by 2 m spacing at and near the extraction wells and uranium plume footprint; then gradually increased to 100 by 100 m spacing farther from the area of interest. The minimum (most southwest) corner of the domain sits at an Easting of 566,650 meters and a Northing of 133,850 meters, and their respective maximums are 569,650 and 135,850 meters (Washington state plane coordinate system, south zone). Figure 4 shows the horizontal gridding of the submodel along with the location of the existing and prospective wells, uranium plume footprint, and constant head boundary.

The hydrogeologic unit identification and hydraulic parameters are consistent with those determined for the Central Plateau Groundwater Model. Layers 1 through 5 of the U Plant model are composed entirely of Ringold gravel Units E and C (BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site*, *South-Central Washington*); including sand facies of the Upper Ringold Unit, where it directly overlies the other E and C units. Layer 6 is composed of a finer grained unit of Ringold Lower Mud, including Ringold Units B and D (BHI-00184). Layer 7 is composed entirely of Ringold Unit A (BHI-00184), a gravel and sand facies that is dominated by sand in the western part of the Pasco Basin. An east-west aligned cross section (Looking north) though the submodel is presented in Figure 5 (a vertical exaggeration of 20 was used) above. The cross section details the hydrostratigraphic unit (HSU), vertical grid spacing, and 2013 water table. Hydraulic parameters are summarized in Table 1. Prior to startup of the 200-ZP-1 pump-and-treat system in July 2012, the hydraulic gradient in the U Plant area averaged 0.0012 m/m toward the east. The hydraulic gradient has changed in response to operation of the 200-ZP-1 system.

A transient simulation was developed to represent the time period from the beginning of 2014 through the end of 2040. Monthly stress periods were used for the period from January 2014 through December 2016, and annual stress periods were used for the period from 2017 through 2040.

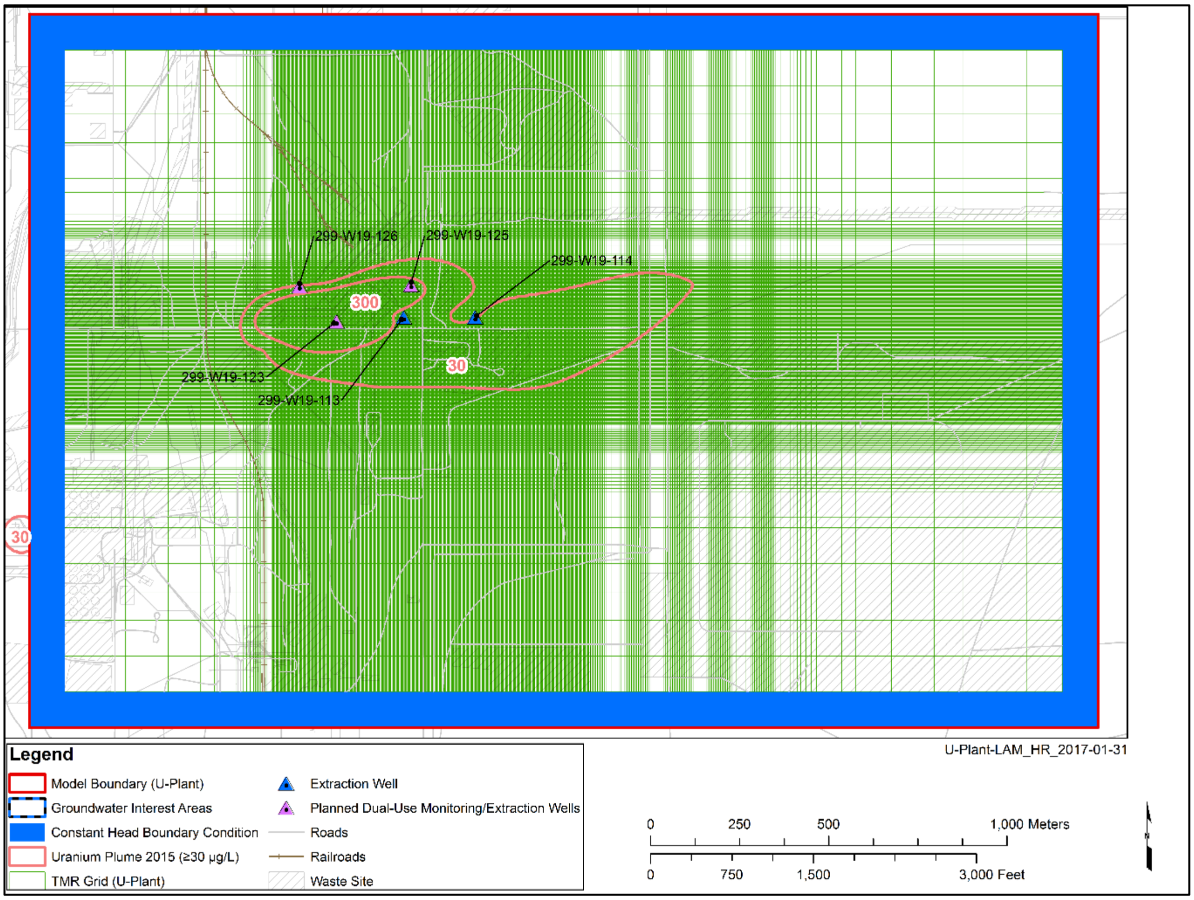

Figure 4. Horizontal Numerical Grid Discretization for the U Plant Submodel

Table 1. Hydraulic Parameters for U Plant Submodel Hydrostratigraphic Units (HSUs)

Layers	Description/Unit	Porosity	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)
1 – 5	Unit 5: Ringold gravel Units E and C (BHI-00184); also includes sand facies of the Upper Ringold Unit where it directly overlies the other E and C units	0.15	5	0.5
6	Unit 8: Fine-grained Ringold Lower Mud including Ringold Units B and D (BHI-00184)	0.15	0.008	0.0008
7	Unit 9: Ringold Unit A (BHI-00184), a gravel and sand facies	0.15	4.8	0.48

Reference: BHI-00184, 1995, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

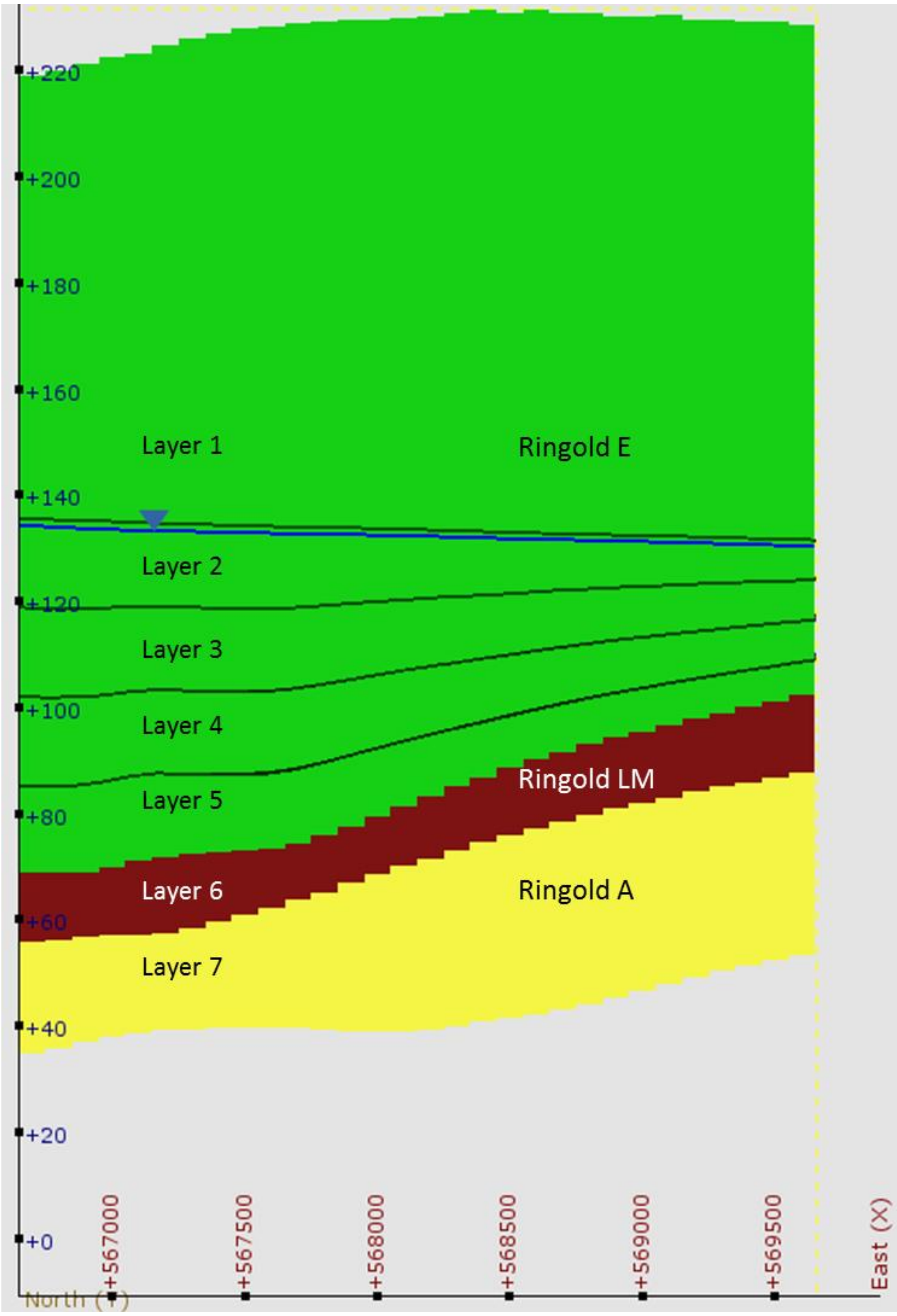

Figure 5. Vertical Numerical Grid Discretization for the U Plant Submodel

4.2 Boundary and Initial Conditions

The Central Plateau Groundwater Model version 8.3.4 model results provided the basis for the boundary and initial conditions of this version of the U Plant Submodel. Hydraulic head results from along the identified submodel boundary and concurrent with the timeframe of the remedial action were extracted from the CPGW Model. These results, interpolated to the refined grid of the submodel, were adopted as prescribed head boundary conditions. These heads changed through time, depending on the results of the stress periods in the CPGW Model that coincide with the timeframe of the remedial action. Initial conditions for the submodel domain were extracted from the results of the CPGW Model for the time representing January, 2014.

4.3 Wells

The location and pumping rates for the two existing extraction wells (Figure *6*) were based on surveyed locations and measured extraction rates. Well 299-W19-113 (Easting 567689.62 and Northing 135008.2) and well 299-W19-114 (Easting 567901.89 and Northing 135013.21) were installed at the end of calendar year 2014. The installed screens extend from elevations of 127.36 to 104.51 meters above mean sea level (amsl) for well 299-W19-113 and from elevations of 128.09 to 105.23 meters amsl for well 299-W19-114, which extends through model layers 2, 3 and 4 for both wells. The locations of two additional prospective extraction wells were based on the surveyed locations of the boreholes and a third prospective extraction well has been proposed. Prospective well 299-W19-123 (Easting 567511.23 and Northing 134988.39) and prospective well 299-W19-125 (Easting 567720.15 and Northing 135090.95) are currently being drilled. Prospective well 299-W19-126 (Easting 567407 and Northing 135087) has yet to be drilled. Because the well screens have not been installed in the prospective wells, the average screen depth intervals of the existing extraction wells were assumed to apply to the prospective wells for modeling purposes.

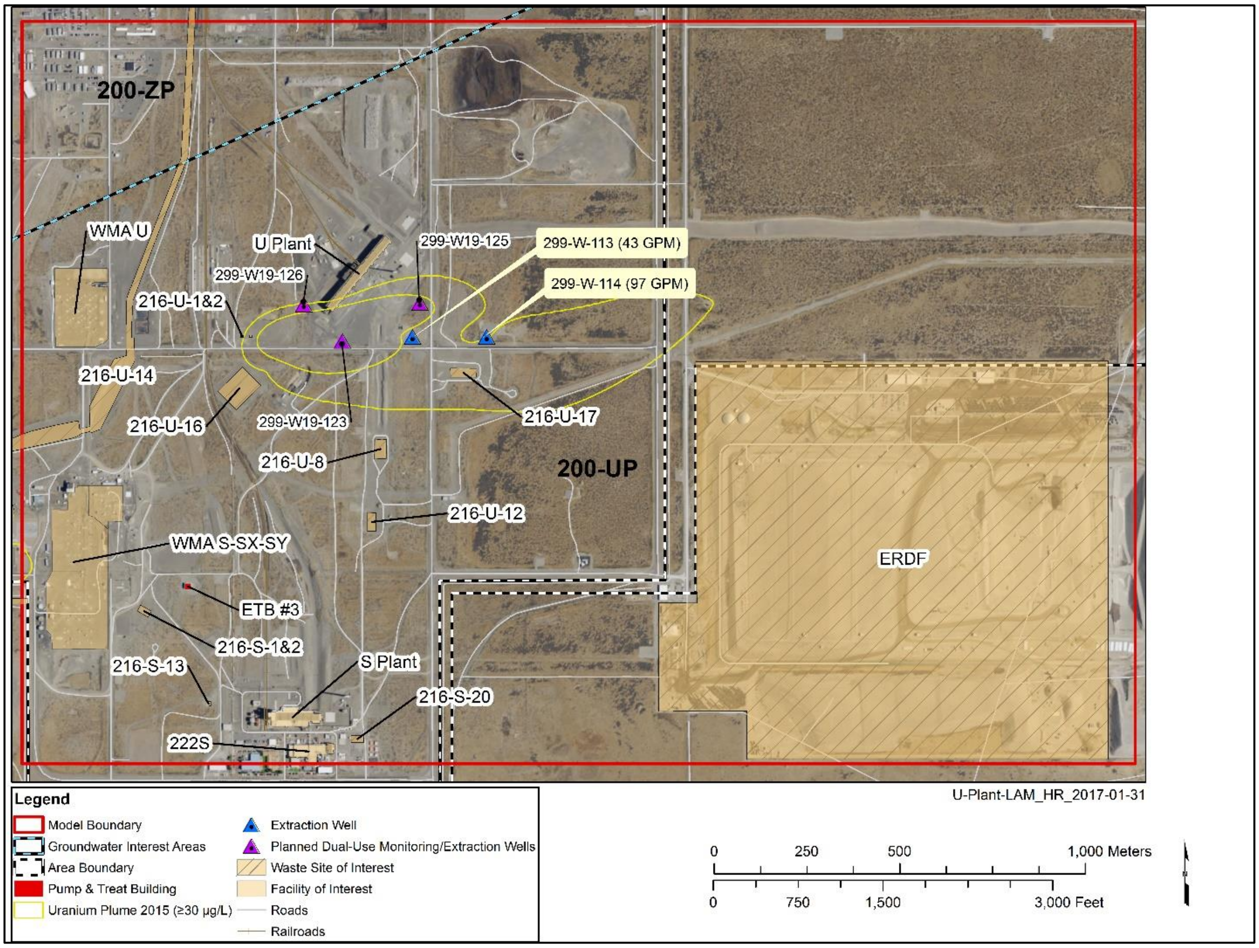

Figure *6*. Extraction Well Locations and Fall 2016 Pumping Rates

5 Software Applications

MODFLOW-2000-MST and MODPATH-MST software programs were used for this environmental calculation. These are CH2M HILL Plateau Remediation Company (CHPRC) approved software, managed and used in compliance with the requirements of PRC-PRO-IRM-309, *Controlled Software Management*. The following supporting information is provided.

5.1 Approved Software

For approved software used in this calculation, the required description is provided.

5.1.1 Description

MODFLOW

- Software Title: MODFLOW-2000-MST
- Software Version: CHPRC Build 8 (executable file mf2k-mst-chprc08dp.exe)
- Hanford Information System Inventory (HISI) Identification Number: 2517 (Safety Software, Level C)
- Authorized Workstation type and property number: Personal Computer, JOHNEWING
- Authorized User: John Ewing
- CHPRC Software Control Documents:
    - CHPRC-00257, *MODFLOW and Related Codes Functional Requirements Document*
    - CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*
    - CHPRC-00259, *MODFLOW and Related Codes Software Test Plan*
    - CHPRC-00260, *MODFLOW and Related Codes Requirements Traceability Matrix*
    - CHPRC-00261, *MODFLOW and Related Codes Acceptance Test Report*

MODPATH

- Software Title: MODPATH-MST
- Software Version: CHPRC Build 6 (executable file modpath-mst-chprc06sp.exe)
- HISI Identification Number: N/A (Support Software; see CHPRC-00258)
- Authorized Workstation type and property number: N/A
- Authorized User: N/A
- CHPRC Software Control Documents:
    - CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*

5.1.2 Software Installation and Checkout

Approved Safety Software packages (MODFLOW) and the controlled version of the support software (MODPATH) were checked out in accordance with procedures specified in CHPRC-00258 Rev. 2. Executable files were obtained from the software owner who maintains the configuration-managed copies in MKS Integrity™[1], installation tests identified in CHPRC-00259 performed and successful installation

[1] MKS Integrity™ is a trademark of MKS, Incorporated.

confirmed, and a Software Installation and Checkout Form was completed and approved for installations used to perform model runs reported in this calculation and is provided in Attachment A to this ECF.

5.1.3 Statement of Valid Software Application

The preparers of this ECF attest that the software identified above, and used for the calculations described in this calculation brief, is appropriate for the application and used within the range of intended uses for which it was tested and accepted by CHPRC.

Because MODFLOW is graded as Level C software, use of this software is required to be logged in the HISI. Accordingly, this ECF has been logged by the software owner in the HISI under Identification Number 2517.

6 Calculation

To test whether the submodel adequately matched the observed drawdown resulting from extraction wells 299-W19-113 and 299-W19-114, the simulations were compared to observed water levels in the AWLN wells. Simulated and observed drawdown hydrographs are depicted in Figure 7 through Figure 10. For the period prior to extraction, which commenced in September 2015, the model closely matches the regional downward trend in the observed water levels. This is an indication that CPGW Model is an accurate representation of the trends in water levels in the area. For the period following September 2015, the model closely matches the observed drawdown in the AWLN wells. This is an indication that the hydraulic properties used in the model are appropriate for approximating the response to extraction in the aquifer.

To test whether the submodel adequately represents the hydraulic gradient in the vicinity of the uranium plume, the simulated magnitude and direction of the hydraulic gradient were compared to values estimated from manually measured water levels in five groups of well triplets (Figure 11). The hydraulic gradient comparison for wells 299-W19-39, 299-W19-46 and 299-W19-48 is depicted in Figure 12 with the well locations, magnitude and direction shown on the top, left and right, respectively. Figure 13 depicts the hydraulic gradient comparison for wells 299-W19-46, 299-W19-49 and 299-W19-105. The hydraulic gradient comparison for wells 299-W19-46, 299-W19-48 and 299-W19-49 is shown in Figure 14. Figure 15 depicts the hydraulic gradient comparison for wells 299-W19-39, 299-W19-48 and 299-W19-101. The hydraulic gradient comparison for wells 299-W19-43, 299-W19-48 and 299-W19-49 is shown in Figure 16.

A baseline simulation was performed to represent operation of the existing extraction wells, 299-W19-113 and 299-W19-114. The simulated water table was compared to the water table map for December 2015 generated from manual water level measurements (Figure 17). The simulated water table is about 0.5 m higher than the mapped water table, although the amount of difference varies across the model domain. The higher simulated water table results from the boundary conditions extracted from the Central Plateau Model, in which the water table is also about 0.5 m higher than field measurements. However, the important feature is that the simulated water table has a very similar shape to the mapped water table. Thus, flow patterns in the model will be similar to flow patterns derived from the mapped water table.

The simulated capture zone for December 2015 is compared to the capture zone determined from mapping of water level measurements in Figure 18. Both are very similar and show that the system is capturing about 60 percent of the uranium plume above 30 µg/L and about 70 percent above 300 µg/L. The current capture zone does not cover the source 216-U-1&2 Cribs.

A suite of MODPATH runs with the reverse particle tracking option were performed to see how much of the plume area was captured by the uranium extraction wells under different well configuration and extraction rate scenarios. Table 2 describes the various pumping scenarios simulated using the flow model along with reverse particle tracking. The particles were placed at each extraction well location at the center of saturated thickness of Layer 2. The resulting capture zones of the MODPATH runs are shown in Figure 19 through Figure 24. Vertical movement of the particles with time is indicated by different colors for each layer (e.g., green indicates that the particle is in layer 3) and each arrow indicates the horizontal distance travelled in a year. The capture zone figures show that particles ending up in Layer 2 generally originate in layer 2 but can also originate in lower layers. The majority of the existing uranium plume is captured in layer 2 in most of the pumping scenarios, regardless. Table 3 shows the percent of capture for both the 300 ug/L and 30 ug/L portions of the uranium plume for each of the extraction scenarios.

Table 2. Flow Rates (gallons per minute) per Well for Optimization Cases

Case	299-W19-113	299-W19-114	299-W19-123	299-W19-125	299-W19-126
opt1	50	50	50	--	--
opt2	50	50	--	50	--
opt3	50	50	--	--	50
opt4	--	100	50	--	--
opt5	--	100	--	50	--
opt6	--	100	--	--	50
opt7	--	100	100	--	--
opt8	--	100	--	100	--
opt9	--	50	50	50	--
opt10	--	100	50	50	--
opt11	--	150	--	150	--
opt12	--	150	--	120	30

Table 3. Simulated Capture Zone Evaluation Metrics

Scenario	Percent of U Plume >30 µg/L Captured	Percent of U Plume >300 µg/L Captured	216-U-1&2 Cribs Within Capture Zone?
(1) W19-113 (50 gpm) W19-114 (50 gpm) W19-123 (50 gpm)	71	100	Yes
(2) W19-113 (50 gpm) W19-114 (50 gpm) W19-125 (50 gpm)	75	100	Yes
(3) W19-113 (50 gpm) W19-114 (50 gpm) W19-126 (50 gpm)	65	83	Yes
(4) W19-114 (100 gpm) W19-123 (50 gpm)	65	66	No
(5) W19-114 (100 gpm) W19-125 (50 gpm)	77	99	No
(6) W19-114 (100 gpm) W19-126 (50 gpm)	58	42	Yes
(7) W19-114 (100 gpm) W19-123 (100 gpm)	73	85	Yes
(8) W19-114 (100 gpm) W19-125 (100 gpm)	78	100	Yes
(9) W19-114 (50 gpm) W19-123 (50 gpm) W19-125 (50 gpm)	74	100	Yes
(10) W19-114 (100 gpm) W19-123 (50 gpm) W19-125 (50 gpm)	80	100	Yes
(11) W19-114 (150 gpm) W19-125 (150 gpm)	87	100	Yes
(12) W19-114 (150 gpm) W19-125 (120 gpm) W19-126 (30 gpm)	84	100	Yes

Note: As of December 2015, the capture zone resulting from operation of the existing extraction wells, 299-W19-113 (55 gpm) and 299-W19-114 (100 gpm), covers 60 percent of the uranium plume above 30 µg/L and 70 percent of the plume above 300 µg/L (DOE/RL-2016-20, *Calendar Year 2015 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations*). The capture zone does not cover the 216-U-1&2 Cribs.

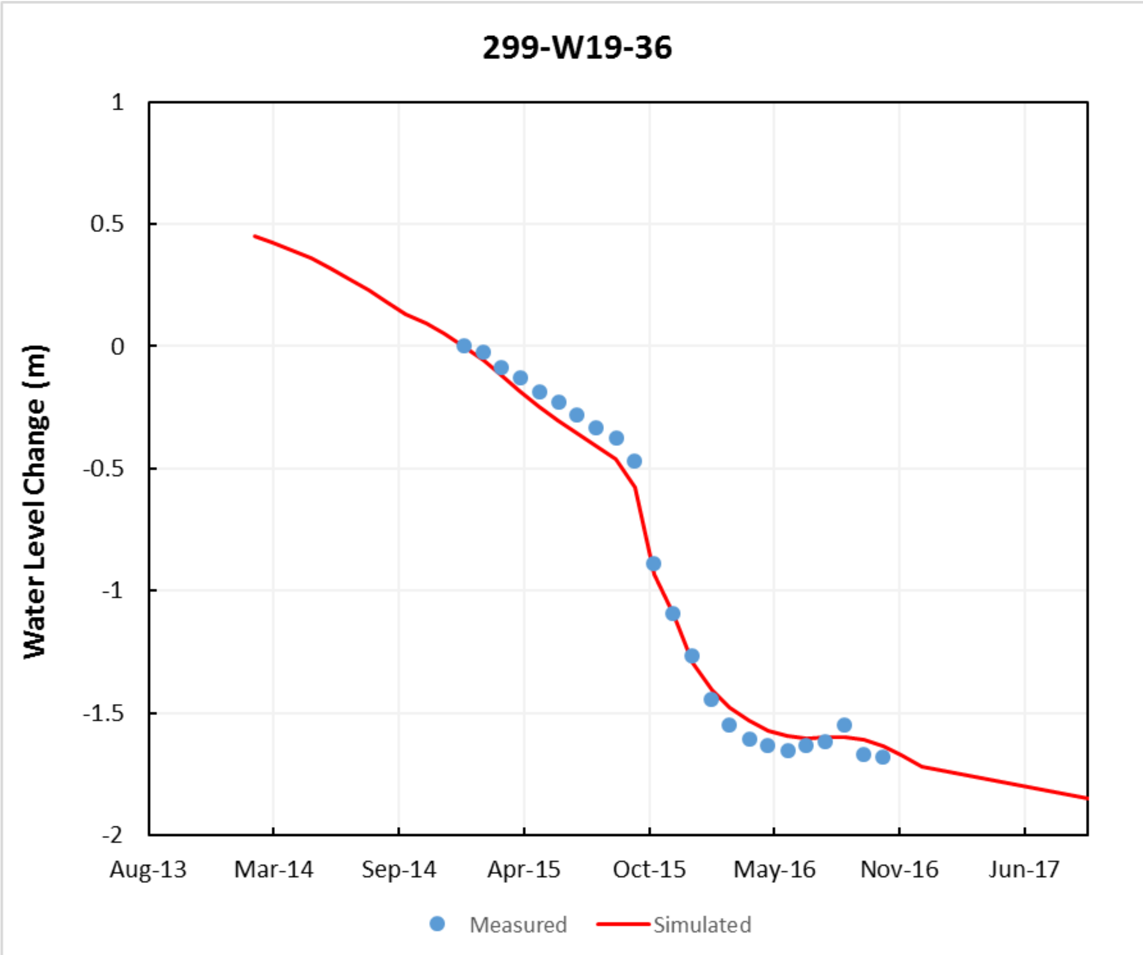

Figure 7. Simulated and Observed Head Change Over Time in Well 299-W-19-36

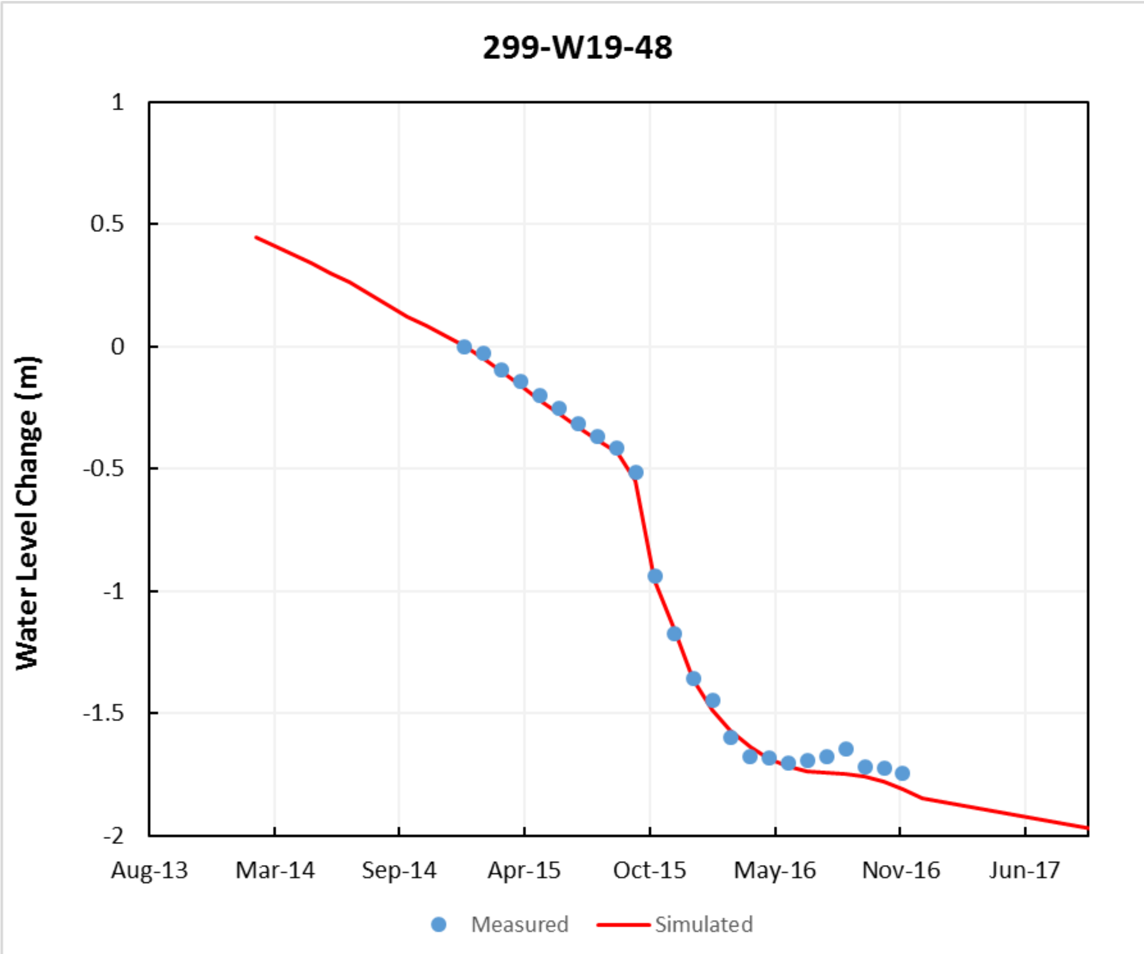

Figure 8. Simulated and Observed Head Change Over Time in Well 299-W-19-48

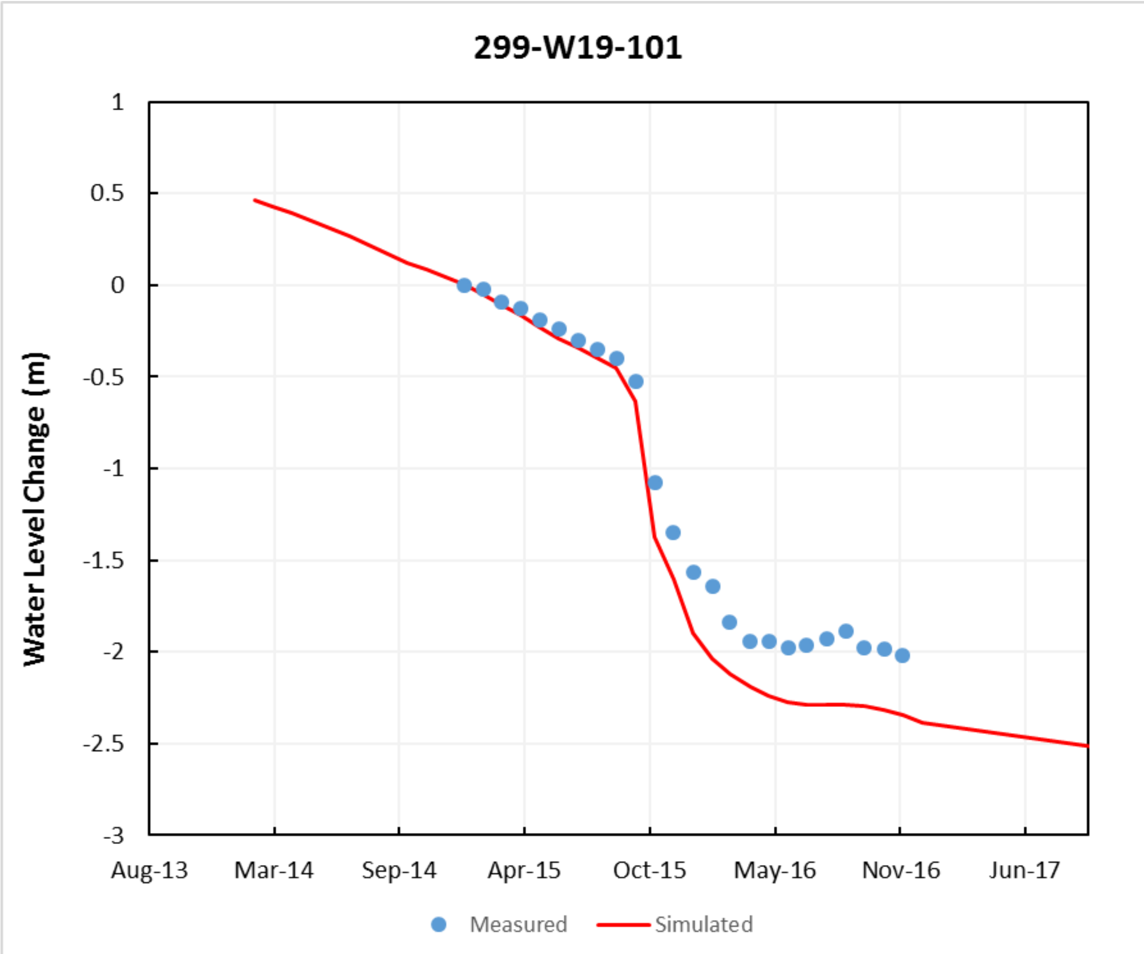

Figure 9. Simulated and Observed Head Change Over Time in Well 299-W-19-101

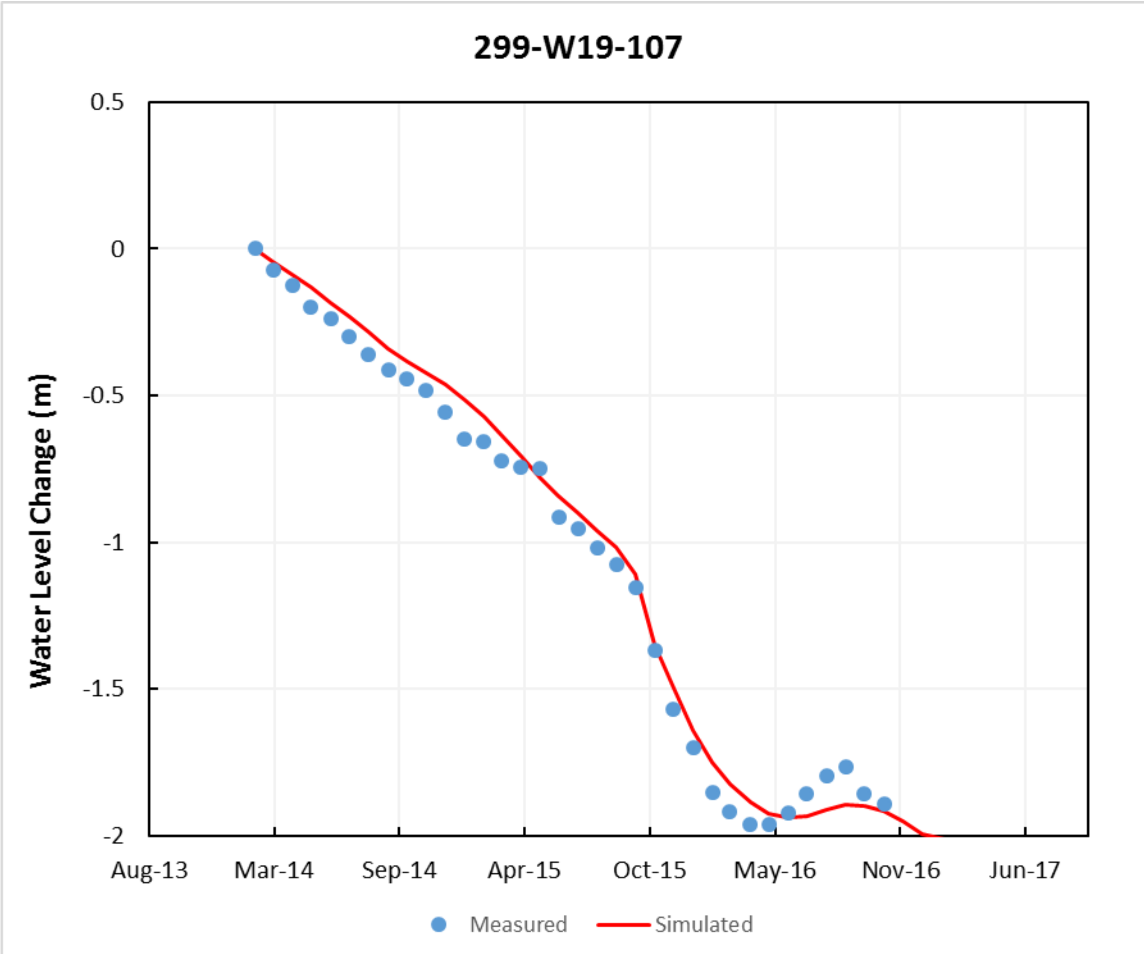

Figure 10. Simulated and Observed Head Change Over Time in Well 299-W-19-107

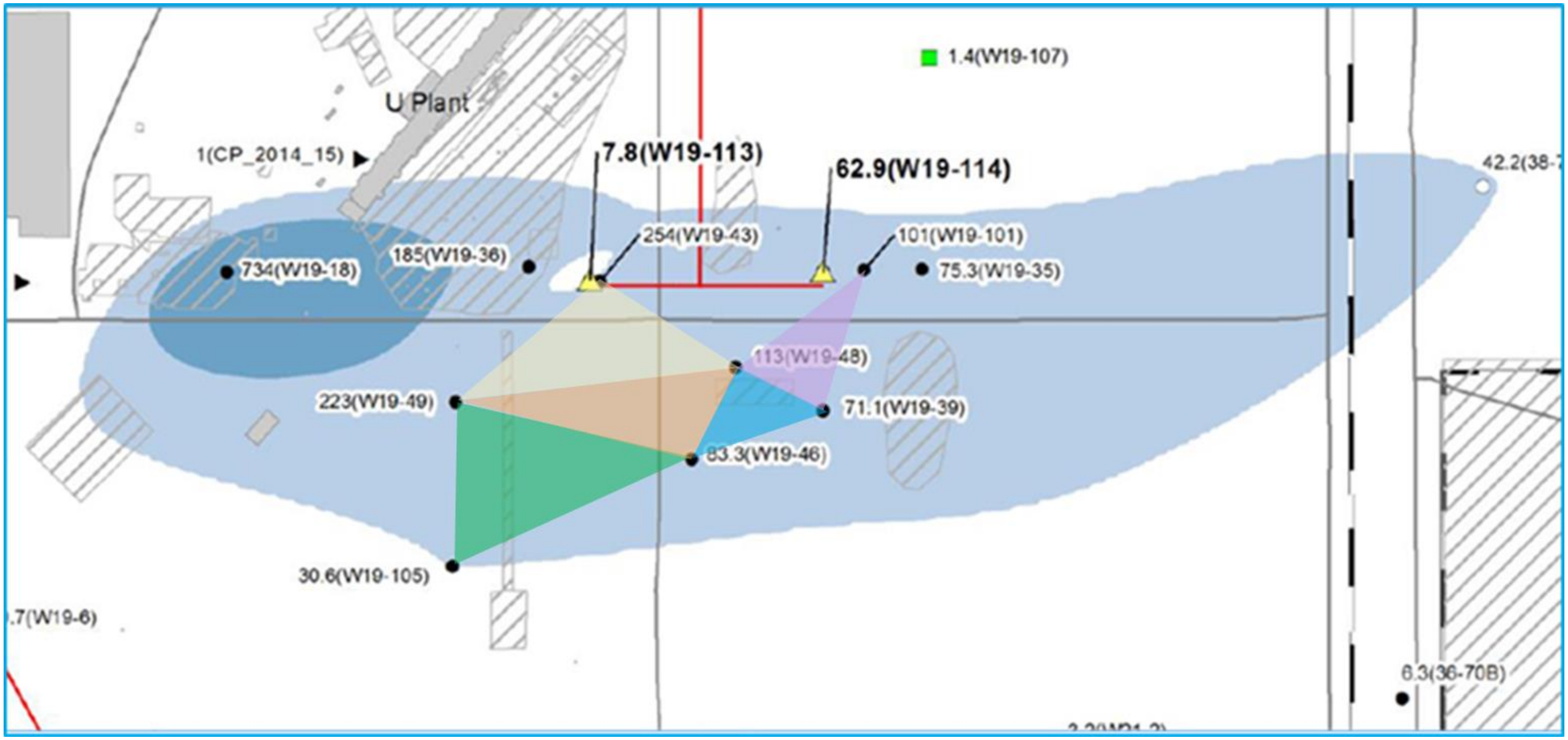

Figure 11. Triangles Representing the Three-point Problem used in the Hydraulic Gradient Analyses

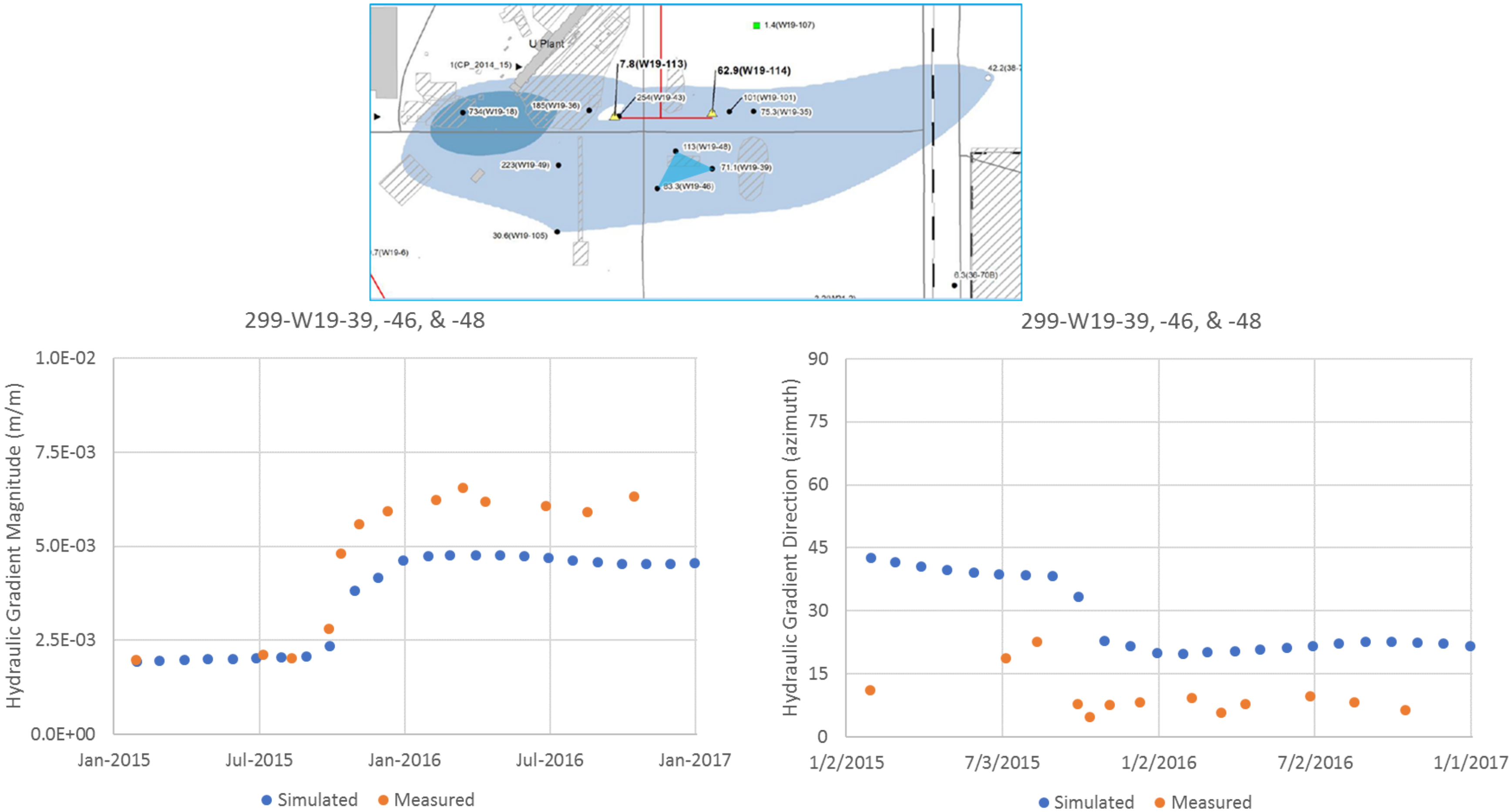

Figure 12. Simulated and Measured Magnitudes and Directions of the Hydraulic C Gradient over Time between Wells 299-W19-39, 299-W19-46 and 299-W19-48

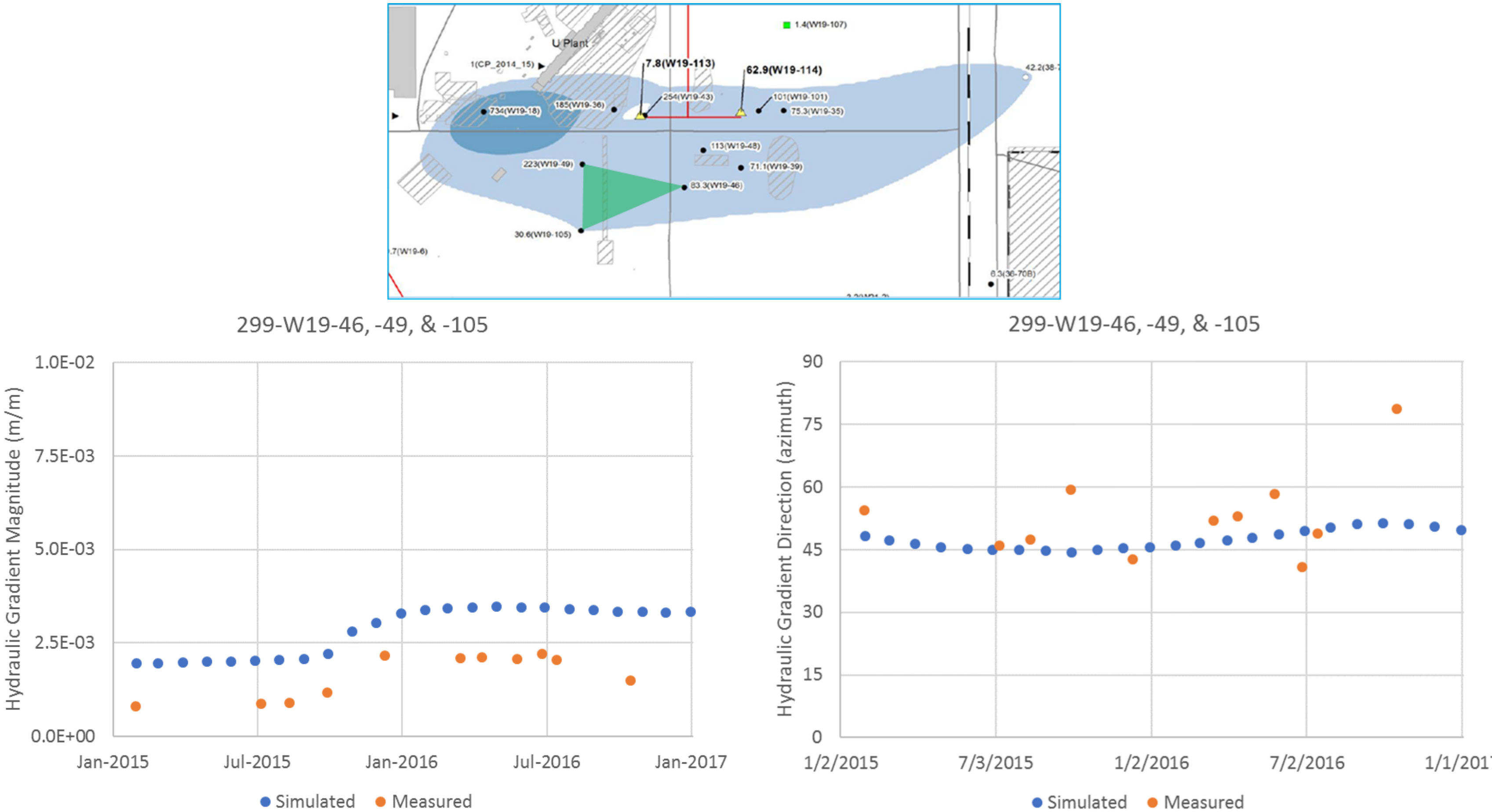

Figure 13. Simulated and Measured Magnitudes and Directions of the Hydraulic Gradient over Time between Wells 299-W19-46, 299-W19-49 and 299-W19-105

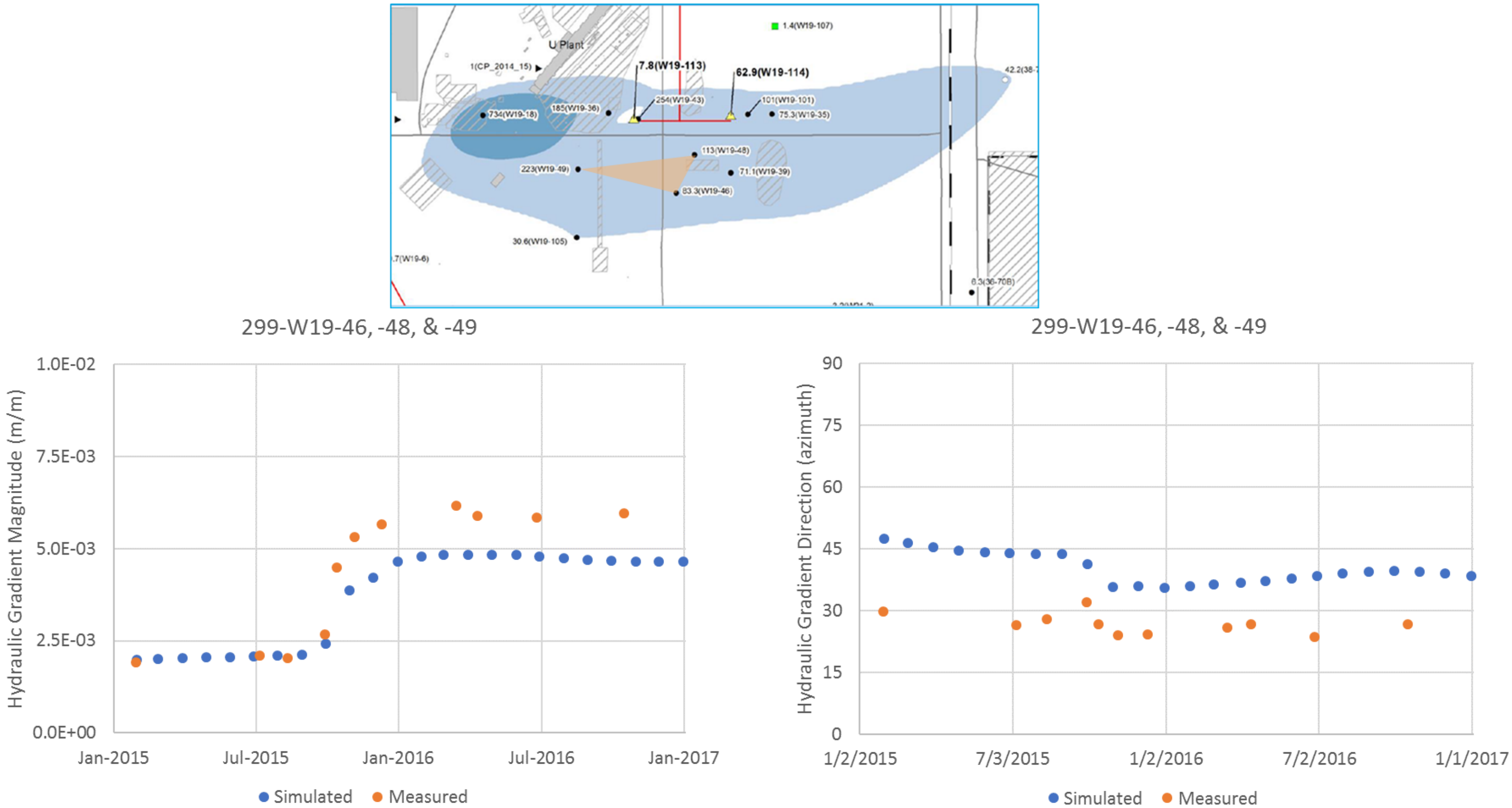

Figure 14. Simulated and Measured Magnitudes and Directions of the Hydraulic Gradient over Time between Wells 299-W19-46, 299-W19-48 and 299-W19-49

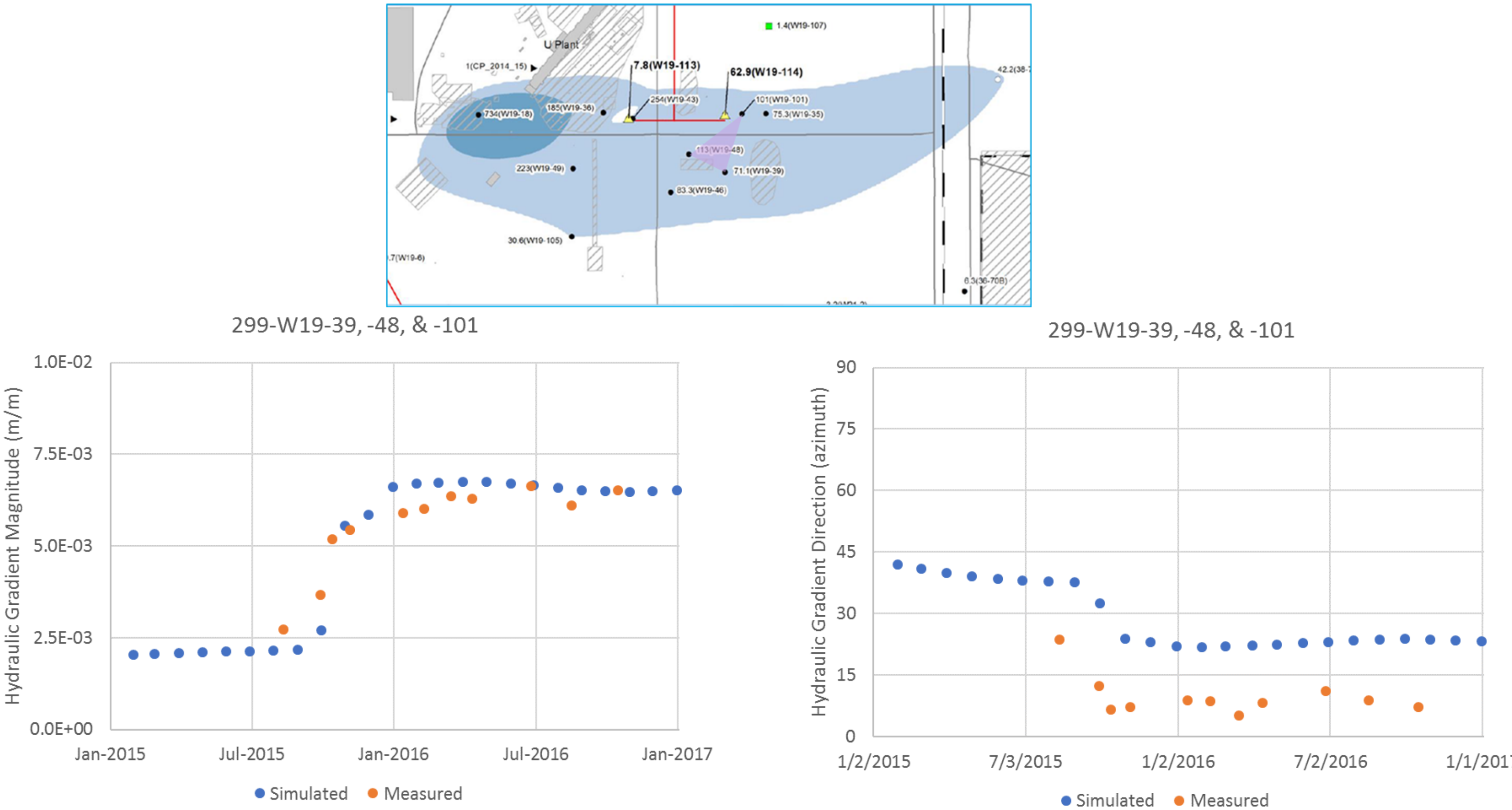

Figure 15. Simulated and Measured Magnitudes and Directions of the hydraulic Gradient over Time between Wells 299-W19-39, 299-W19-48 and 299-W19-101

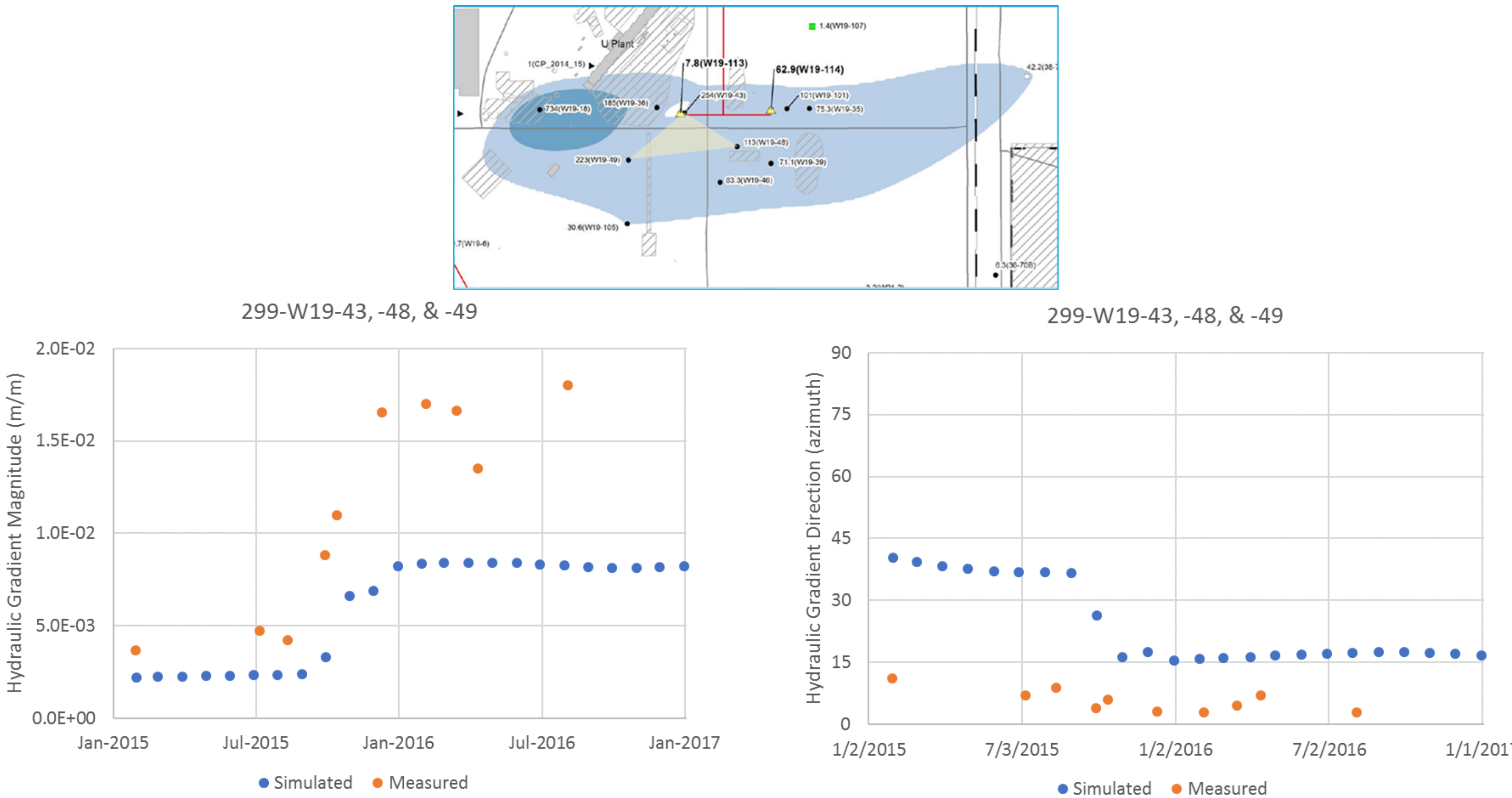

Figure 16. Simulated and Measured Magnitudes and Directions of the Hydraulic Gradient over Time between Wells 299-W19-43, 299-W19-48 and 299-W19-49

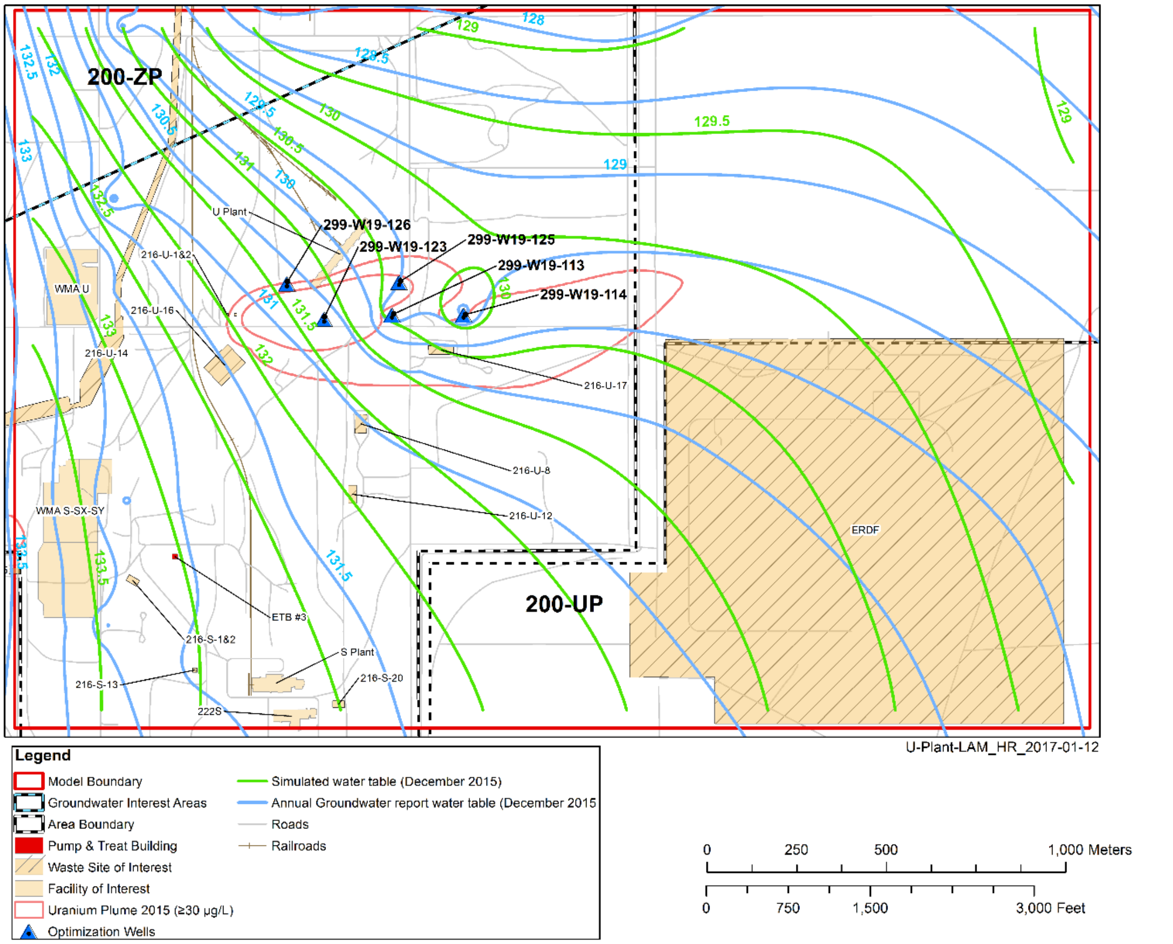

Figure 17. Comparison of Simulated and Mapped Water Table, December 2015

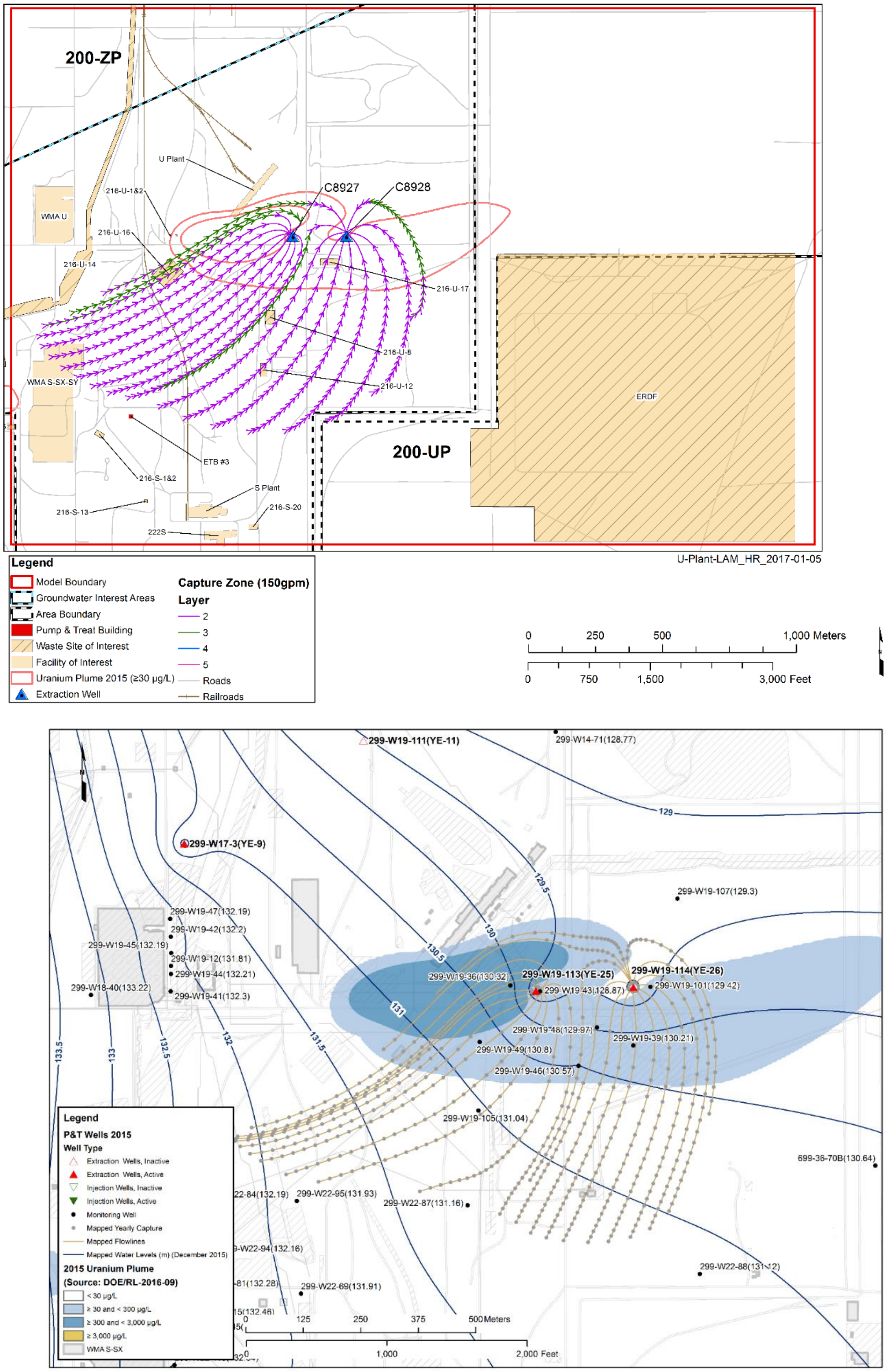

Figure 18. Comparison of Simulated (top) and Mapped (bottom) Capture Zone, December 2015

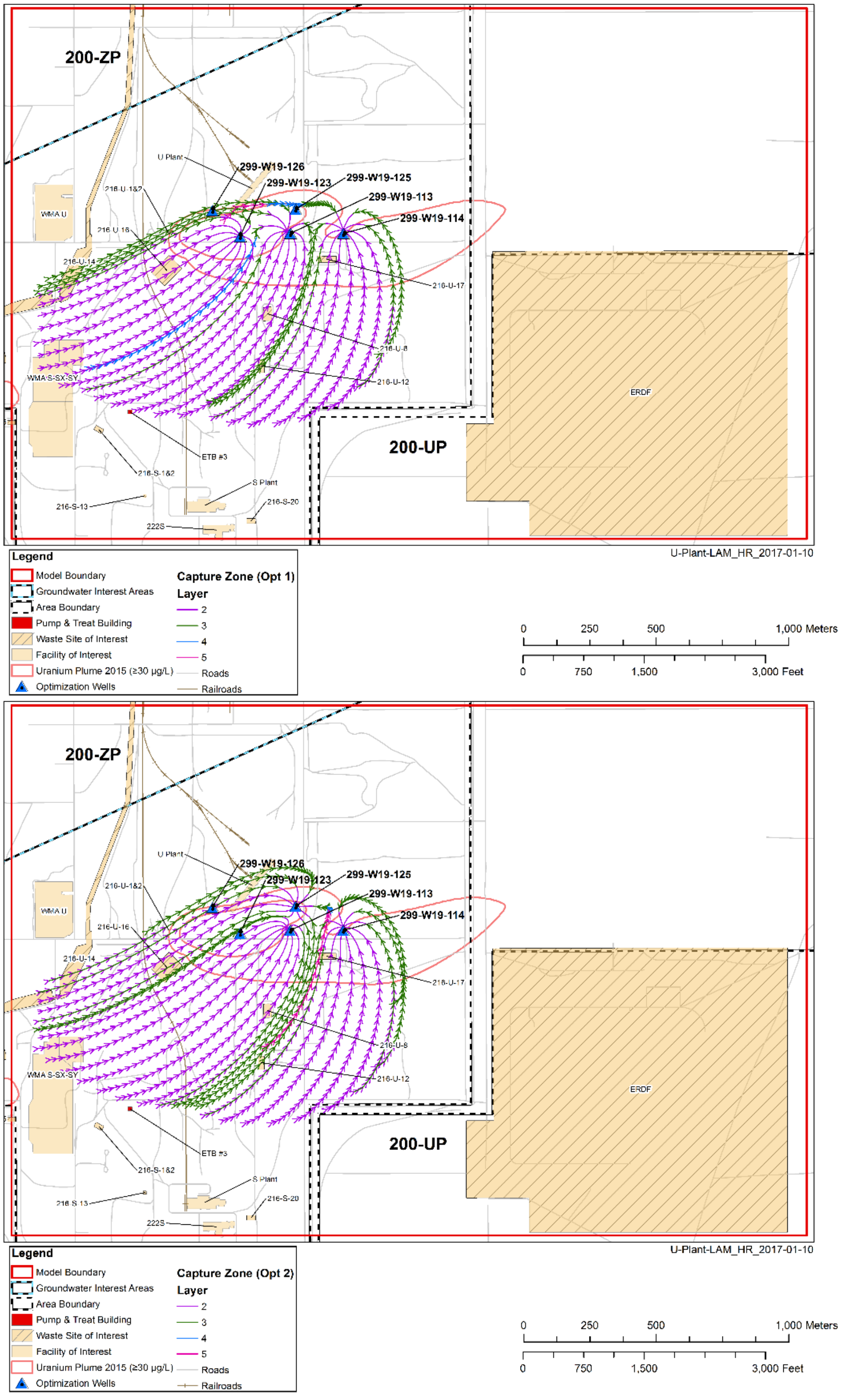

Figure 19. Capture Zone Maps for opt1 (upper) and opt2 (lower) Extraction Scenarios

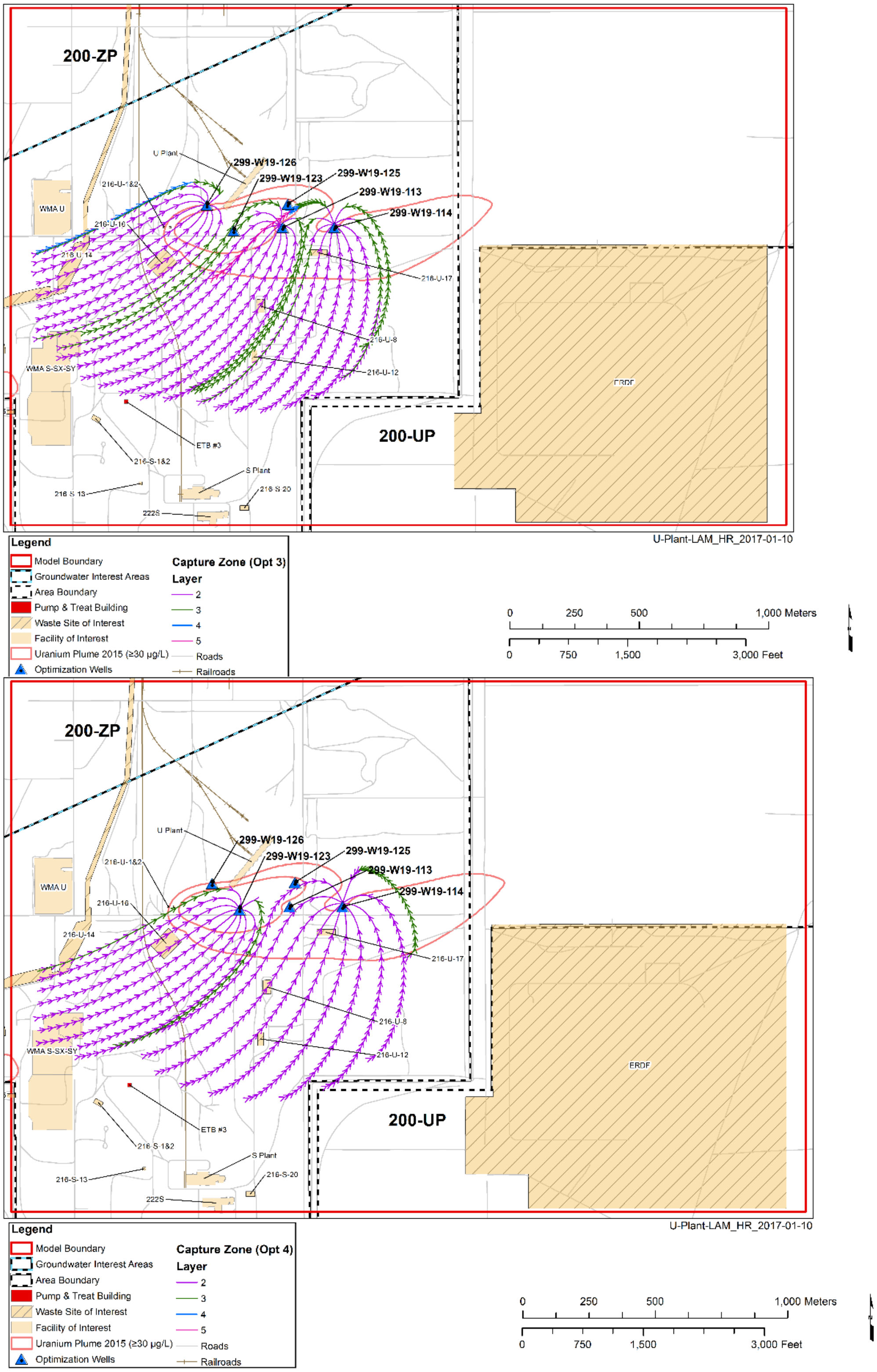

Figure 20. Capture Zone Maps for opt3 (upper) and opt4 (lower) Extraction Scenarios

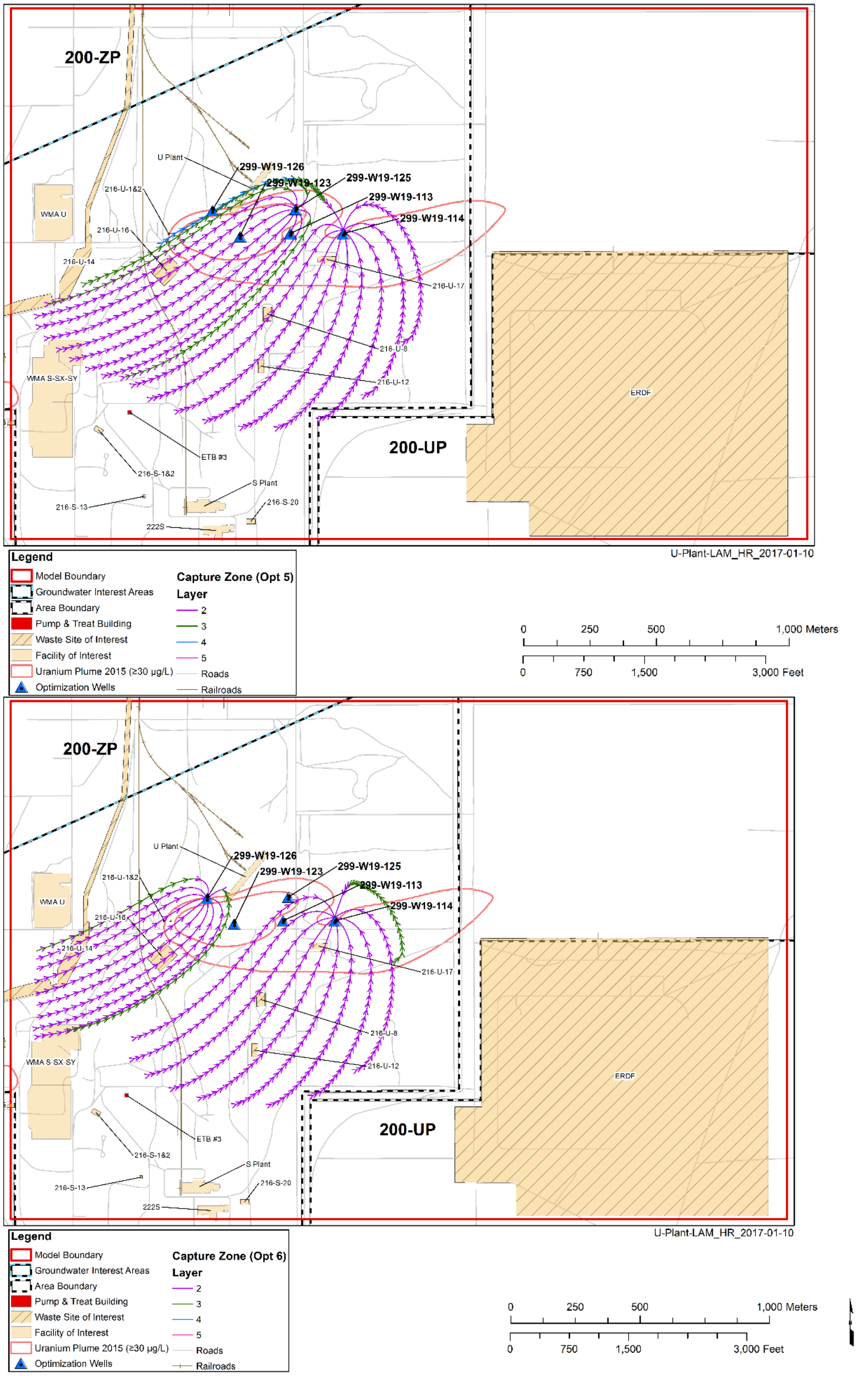

Figure 21. Capture Zone Maps for opt5 (upper) and opt6 (lower) Extraction Scenarios

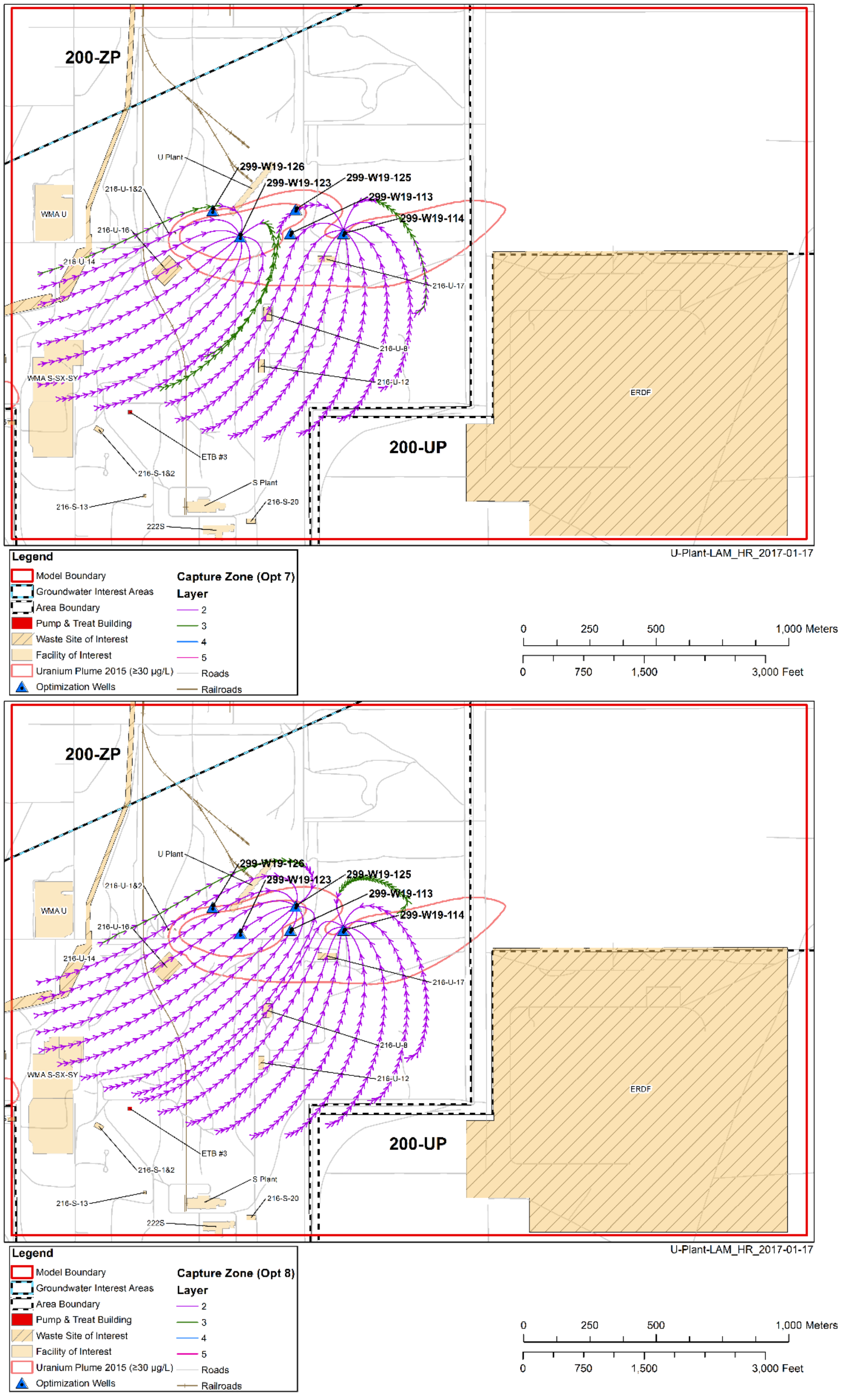

Figure 22. Capture Zone Maps for opt7 (upper) and opt8 (lower) Extraction Scenarios

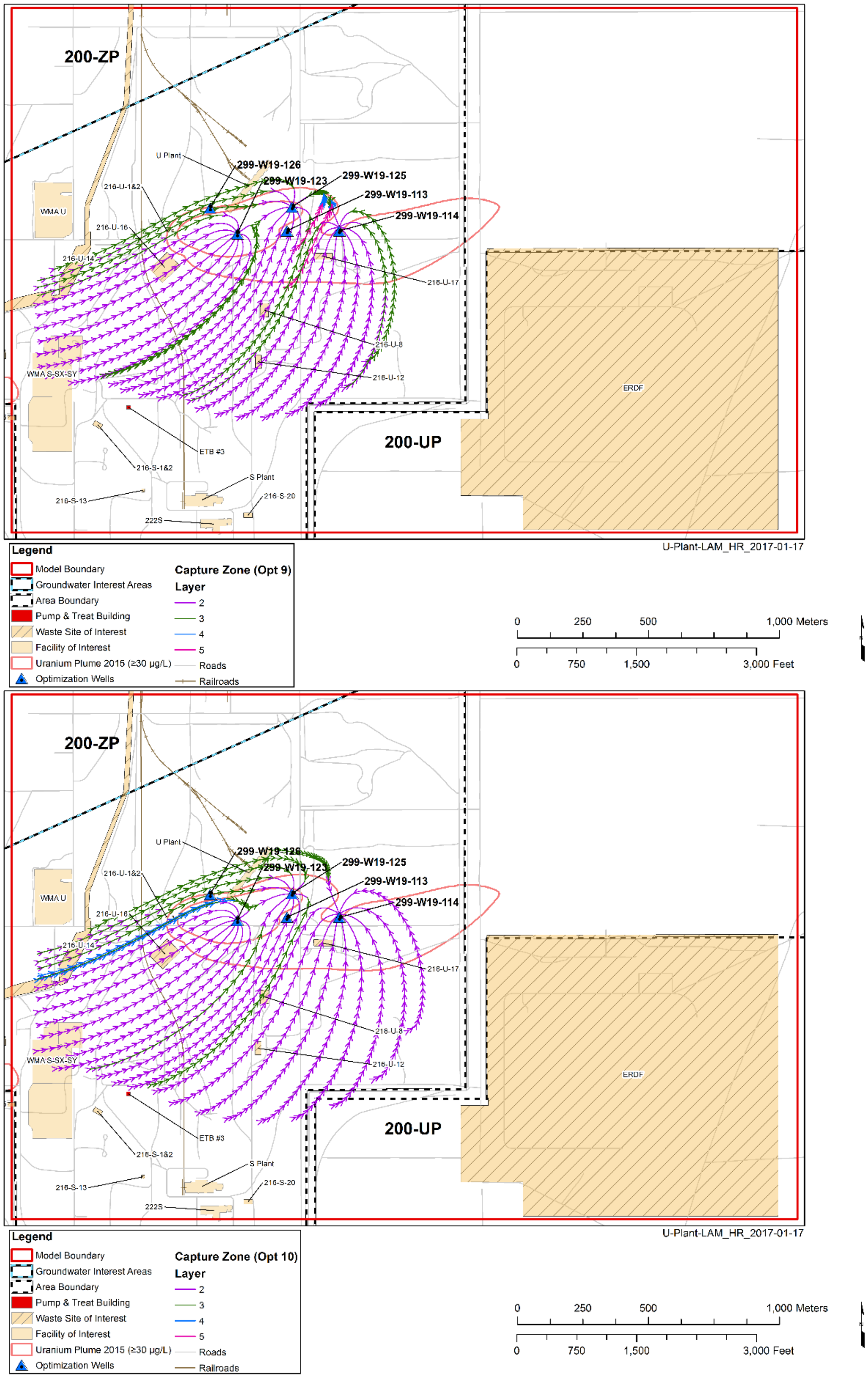

Figure 23. Capture Zone Maps for opt9 (upper) and opt10 (lower) Extraction Scenarios

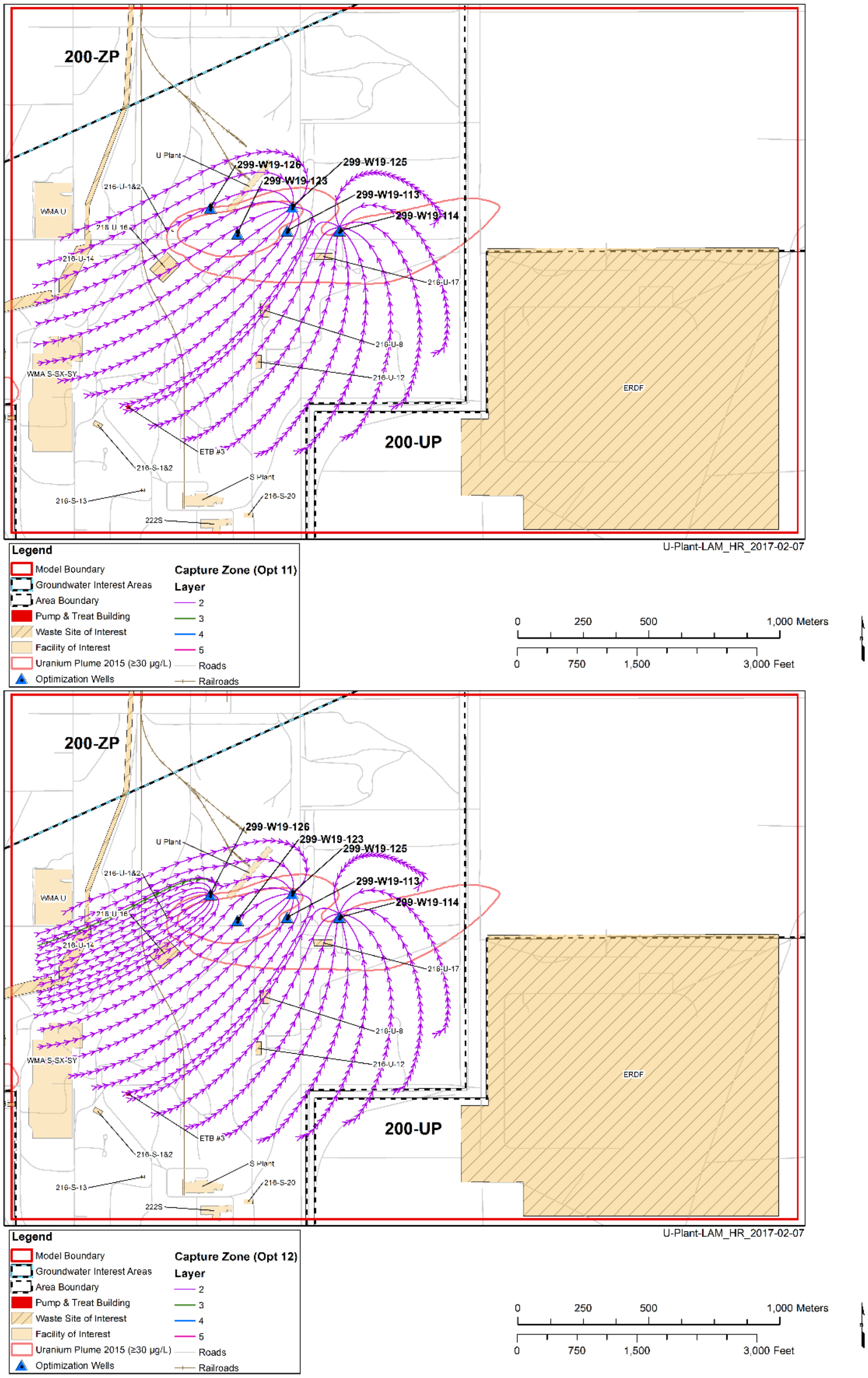

Figure 24. Capture Zone Maps for opt11 (upper) and opt12 (lower) Extraction Scenarios

7 Results/Conclusions

The simulation results suggest that several well configuration scenarios (opt1, opt2, opt8, opt9, opt10, opt11 and opt12) are capable of containing the entirety of the high concentration portion (>300 µg/L) of the uranium plume over time along with the area beneath the 216-U-1 and 216-U-2 Cribs. Three scenarios (opt3, opt6 and opt7) capture the area beneath the cribs but do not capture 100 percent of the high concentration portion of the uranium plume. Two scenarios (opt4 and opt5) captured neither the area beneath the cribs nor the entirety of the high concentration portion of the plume although opt5 captures 99 percent of it. None of the scenarios capture the entirety of the portion of the plume between 30 µg/L and 300 µg/L but seven of the scenarios capture over 70 percent of this portion of the plume. This uncaptured portion of the plume is expected to migrate toward the north-east side of the model. Scenario opt10 scored the best on the capture zone evaluation metrics. It should be noted that scenario opt10 includes a total of 200 gpm pumping, whereas some other scenarios (opt2 and opt9) scored comparably while pumping a total of 150 gpm.

8 References

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Attachment A

Software Installation and Checkout Form: MODFLOW and Related Codes

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: MODFLOW and Related Codes   Software Version No.: Bld 8

EXECUTABLE INFORMATION:

2. Executable Name (include path):

```
Following executable files in directory: [redacted]
\bin-windows

MD5 Signature (unique ID)          Executable File Name
--------------------------------   ------------------------   -----------------------------
919F74196F5FB5BF0364FC373011B507   mf2k-chprc08dpl.exe        MODFLOW-2000 double precision
EAF037703ADD2C62CDD9CBC47468D2F6   mf2k-chprc08spl.exe        MODFLOW-2000 single precision
4E7F29DD5496D2CBA7144ADACB13DAAD   mf2k-mst-chprc08dpv.exe    MODFLOW-2000-MST single prec
CEB80288C616E0552E4CE5A2D4719387   mf2k-mst-chprc08spv.exe    MODFLOW-2000-MST double prec
ECA9828530B68D2D7C34078C019D5D0C   mt3d-chprc08dpl.exe        MT3DMS double precision
0920CC235862665D9400A3FC80F682DD   mt3d-chprc08spl.exe        MT3DMS single precision
5C61432D2C898E83DDFE242C52A755AB   mt3d-mst-chprc08dpv.exe    MT3DMS-MST double precision
68F89DAF2E6913D2578DE53CBD34FBA0   mt3d-mst-chprc08spv.exe    MT3DMS-MST single precision
```

3. Executable Size (bytes): MD5 signatures listed above uniquely identify executable files

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   Vendor Provided (SSP&A)

5. Operating System (include version number):

   Vendor Provided (SSP&A)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   Personal Computer, JOHNEWING

7. Operating System (include version number):

   Windows 10 Pro

8. Open Problem Report? (●) No ( ) Yes   PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   [redacted]\test-windows

10. Procedure(s):

    CHPRC-00259 Rev 3, MODFLOW and Related Codes Software Test Plan

11. Libraries:

    N/A (static linking)

12. Input Files:

    MF-ITC-1 and MT-ITC-1 inputs

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: MODFLOW and Related Codes   Software Version No.: Bld 8

13. Output Files:

MF-ITC-1 and MT-ITC-1 outputs

14. Test Cases:

MF-ITC-1 (both standard and MST versions of MODFLOW)- run for single & double precision
MT-ITC-1 - run for single and double precision

15. Test Case Results:

All installation tests were successful.

16. Test Performed By: John Ewing

17. Test Results: ◉ Satisfactory, Accepted for Use ○ Unsatisfactory

18. Disposition (include HISI update): HISI entries for MODFLOW & MT3DMS updated to add installation and user. -WEN

Prepared By:

19. William E. Nichols (Digitally signed by William E. Nichols DN: cn=William E. Nichols, o=CHPRC, ou=Risk & Modeling Integration, email=william_e_nichols@rl.gov, c=US Date: 2017.02.01 14:38:45 -08'00')

Software Owner (Signature)	Print	Date
William E. Nichols	WE Nichols	

20. Test Personnel:

Sign	Print	Date
[signature]	John Ewing	2/1/17

Approved By:

21.

Software SME (Signature)	Print	Date
	N/R (CHPRC-00258 Rev 3)	