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Calendar Year 2016 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations

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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Executive Summary

This report presents the annual remediation performance evaluation for the 200-UP-1 and 200-ZP-1 Operable Units (OUs) at the Hanford Site for calendar year (CY) 2016. The 200-ZP-1 OU includes operation of the 200 West Pump and Treat (P&T) Facility and extraction and injection system. The 200-UP-1 OU includes the Waste Management Area (WMA) S-SX groundwater extraction system, U Plant area P&T, and iodine-129 plume hydraulic containment. This year, the report also summarizes performance of groundwater extraction from the 200-DV-1 deep vadose zone OU and the 200-BP-5 groundwater OU. These remediation systems are operated by CH2M HILL Plateau Remediation Company for the U.S. Department of Energy.

Groundwater remediation within the 200-ZP-1 OU is conducted in accordance with a record of decision[1] (ROD) issued in 2008, and groundwater remediation for the 200-UP-1 OU is conducted in accordance with an interim remedial action ROD[2] issued in 2012. Non-time critical removal actions for the 200-BP-5 and 200-DV-1 OUs are being conducted in accordance with approved action memoranda.[3,4]

The 200 West P&T design currently consists of 26 extraction and 27 injection wells, with an installed capacity to treat up to 9,464 L/min (2,500 gpm) of extracted groundwater. During 2016, the average combined influent flow rate through the 200 West P&T was 5,847 L/min (1,544 gpm). The total volume treated in 2016 through the 200 West P&T was 3,038.7 million L (802.2 million gal), removing 1,721 kg of carbon tetrachloride, 330,877 kg of nitrate, 69.7 kg of chromium (total and hexavalent), 8.6 kg of trichloroethene, and 147 g (2.52 Ci) of technetium-99. Iodine-129 removal was

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[1] EPA, Ecology, and DOE, 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=00098825.

[2] EPA, Ecology, and DOE, 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0091413.

[3] DOE/RL-2016-41, 2016, *Action Memorandum for 200-BP-5 Operable Unit Groundwater Extraction*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0073242H.

[4] DOE/RL-2014-34, 2014, *Action Memorandum for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0082284H.

negligible, as the influent and effluent concentrations throughout 2016 were less than the detection limit of 0.6 pCi/L.

The WMA S-SX groundwater extraction system operated throughout 2016 to remediate technetium-99 near the S-SX Tank Farms in the 200-UP-1 OU. Comingled chromium, nitrate, and carbon tetrachloride is also removed from groundwater at this location. The system began operating in late 2012 and consists of three extraction wells, aboveground pipelines, and a transfer building to pump extracted groundwater to the 200 West P&T for treatment and reinjection. The system operated greater than 90 percent of the time during 2016. When operating, typical flow rates for the system were 345 L/min (91 gpm), meeting the design nominal pumping rate of 303 L/min (80 gpm). The total volume of water extracted from the aquifer during 2016 was 167 million L (44.1 million gal), and the system removed 22.3 g (0.378 Ci) of technetium-99, 5.4 kg of chromium, 4,910 kg of nitrate, and 11.4 kg of carbon tetrachloride.

The U Plant area P&T and the iodine-129 plume hydraulic containment system began operating in 2015 as part of the 200-UP-1 remedy. The U Plant area P&T system began operating during September 2015. Groundwater is extracted from two wells and pumped to the 200 West P&T for treatment. Modifications to the 200 West P&T radiological building to add an ion exchange treatment train to remove uranium from extracted water were also completed during 2015. Between startup and the end of 2016, the U Plant area P&T operated at an average rate of 571 L/min (151 gpm). The total volume of water extracted from the aquifer during 2016 was 301 million L (80 million gal), and the system removed 25.7 g (0.47 Ci) of technetium-99, 9.9 kg of uranium, 48,800 kg of nitrate, and 24.4 kg of carbon tetrachloride.

The iodine-129 plume hydraulic containment system consists of three hydraulic control wells for injecting treated water from the 200 West P&T to the east of the iodine-129 plume boundary (between 200 West and 200 East Areas). Hydraulic containment is provided through increasing the water table elevation downgradient of the plume to slow its eastward migration while treatment technologies are evaluated. The three hydraulic control injection wells were drilled during 2015 and began operating on October 28, 2015. Monthly water level measurements began in September 2015 from a network of wells near the injection wells. Potentiometric surface maps prepared using multi-event universal kriging from the water level measurements. The water table maps show small groundwater mounds around the injection wells, but with just over 1 year of injection, it

is too early to assess the effect of the injection well operation on hydraulic gradients in the area and migration of the iodine-129 plume.

In 2016, the 200 West P&T also received extracted groundwater from the 200-DV-1 OU, 200-BP-5 OU, and Environmental Restoration Disposal Facility (ERDF) leachate for treatment. Extracted from the 200-DV-1 OU and 200-BP-5 OU includes perched water in the deep vadose zone and groundwater from the unconfined aquifer, respectively, from the B Complex Area located in the 200 East Area. Extracted groundwater from 200-BP-5 is transferred via pipeline to the 200 West P&T. Perched groundwater extracted from the 200-DV-1 OU was transferred by truck to an offload system inlet tank at the 200 West P&T. In 2016, construction began to connect the 200-DV-1 perched water extraction wells to the 200-BP-5 OU groundwater pipeline for transfer to the 200 West P&T. Construction was completed in 2016 to install a transfer line for ERDF leachate to the 200 West P&T.

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Terms

AMT	aerated membrane tank
AWLN	automated water level network
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
CPGWM	Central Plateau Groundwater Model
CY	calendar year
DCS	derived concentration standard
DOE	U.S. Department of Energy
DS	decision statement
DWS	drinking water standard
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FBR	fluidized bed reactor
FS	feasibility study
GAC	granular-activated carbon
HEIS	Hanford Environmental Information System
IC	institutional control
IX	ion exchange
LLWMA	low-level waste management area
MBR	membrane bioreactor
MCL	maximum contamination level
MEUK	multi-event universal kriging
MNA	monitored natural attenuation
MTCA	"Model Toxics Control Act—Cleanup" (WAC 173-340)
NTCRA	non-time-critical removal action

N/A	not applicable
O&M	operations and maintenance
OU	operable unit
P&T	pump and treat
PFP	Plutonium Finishing Plant
PMP	performance monitoring plan
PNNL	Pacific Northwest National Laboratory
PQL	practical quantitation limit
PVC	polyvinyl chloride
PUREX	Plutonium-Uranium Extraction (Plant)
QA	quality assurance
QC	quality control
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
RD/RAWP	remedial design/remedial action work plan
REDOX	Reduction-Oxidation (Plant)
RI	remedial investigation
RLM	Ringold lower mud
ROD	record of decision
SALDS	State-Approved Land Disposal Site
SAP	sampling and analysis plan
SST	single-shell tank
SVE	soil vapor extraction
TCE	trichloroethene
TED	total effective dose
TEDF	Treated Effluent Disposal Facility
UCL_{95}	95 percent confidence limit
VOC	volatile organic compound
WMA	waste management area

1 Introduction

This report presents the calendar year (CY) 2016 operational results and evaluations for the 200-UP-1 and 200-ZP-1 Groundwater Operable Unit (OU) pump and treat (P&T) systems, the 200-DV-1 deep perched water extraction system, and the 200-BP-5 groundwater extraction systems at the Hanford Site. In 2016, extracted groundwater and perched water were routed from all four OUs to the 200 West P&T facility for treatment and reinjection. These systems are operated by CH2M HILL Plateau Remediation Company (CHPRC) for the U.S. Department of Energy (DOE). Figure 1-1 depicts the Hanford Site 200 West Area and the locations of the 200 West P&T, Waste Management Area (WMA) S-SX groundwater extraction system, U Plant area P&T, iodine-129 hydraulic containment injection wells, 200-DV-1 perched water extraction, 200-BP-5 groundwater extraction, the Environmental Restoration Disposal Facility (ERDF), and associated waste sites.

The 200 West P&T became operational in July 2012, replacing the interim 200-ZP-1 OU system, to capture and treat contaminated groundwater. The 200 West P&T is designed to reduce the mass of contaminants of concern (COCs) throughout the 200-ZP-1 OU by a minimum of 95% in 25 years from startup. The COCs include carbon tetrachloride, total and hexavalent chromium, iodine-129, nitrate, technetium-99, trichloroethene, and tritium. The 200 West P&T has been implemented in combination with monitored natural attenuation (MNA) to achieve cleanup levels for all COCs in 125 years from startup. EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Operable Unit Superfund Site Benton County, Washington* (hereafter referred to as the 200-ZP-1 Record of Decision [ROD]), provides the regulatory framework for remediation of the 200-ZP-1 OU.

The WMA S-SX groundwater extraction system is located in the 200-UP-1 OU near the S-SX Tank Farms and focuses on technetium-99 removal from the aquifer. Technetium-99 occurs as a groundwater contaminant beneath and downgradient of the SX Tank Farm in the southern portion of the 200 West Area. The WMA S-SX groundwater extraction system consists of three extraction wells, aboveground pipelines, and a transfer building to capture and pump contaminated groundwater near the S-SX Tank Farms to the 200 West P&T for treatment. The WMA S-SX groundwater extraction system began operations in 2012.

The U Plant area P&T system, which began operating in September 2015, focuses on uranium and technetium-99 removal from the aquifer. It consists of two extraction wells and aboveground, dual-walled pipelines for freeze protection to convey extracted groundwater to the radiological building of the 200 West P&T for treatment. Modifications to the radiological building to add an ion exchange (IX) treatment train to remove uranium from the extracted water were completed during 2015. Groundwater from the U Plant area extraction wells is treated through the uranium IX treatment train at the 200 West P&T. The water is then combined with water from other 200-ZP-1 OU extraction wells requiring radiological treatment to remove technetium-99 (and low concentrations of iodine-129). The treated water is then returned to the aquifer using injection wells.

The iodine-129 plume hydraulic containment component of the 200-UP-1 OU remedy consists of three hydraulic control injection wells that inject treated water from the 200 West P&T to the east of the iodine-129 plume boundary. The three hydraulic control injection wells were drilled during 2015 and began operating on October 28, 2015. Water level measurements are used to determine the effectiveness of the hydraulic control remedy. Groundwater remediation of the 200-UP-1 OU is addressed by EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit* (hereafter referred to as the 200-UP-1 ROD).

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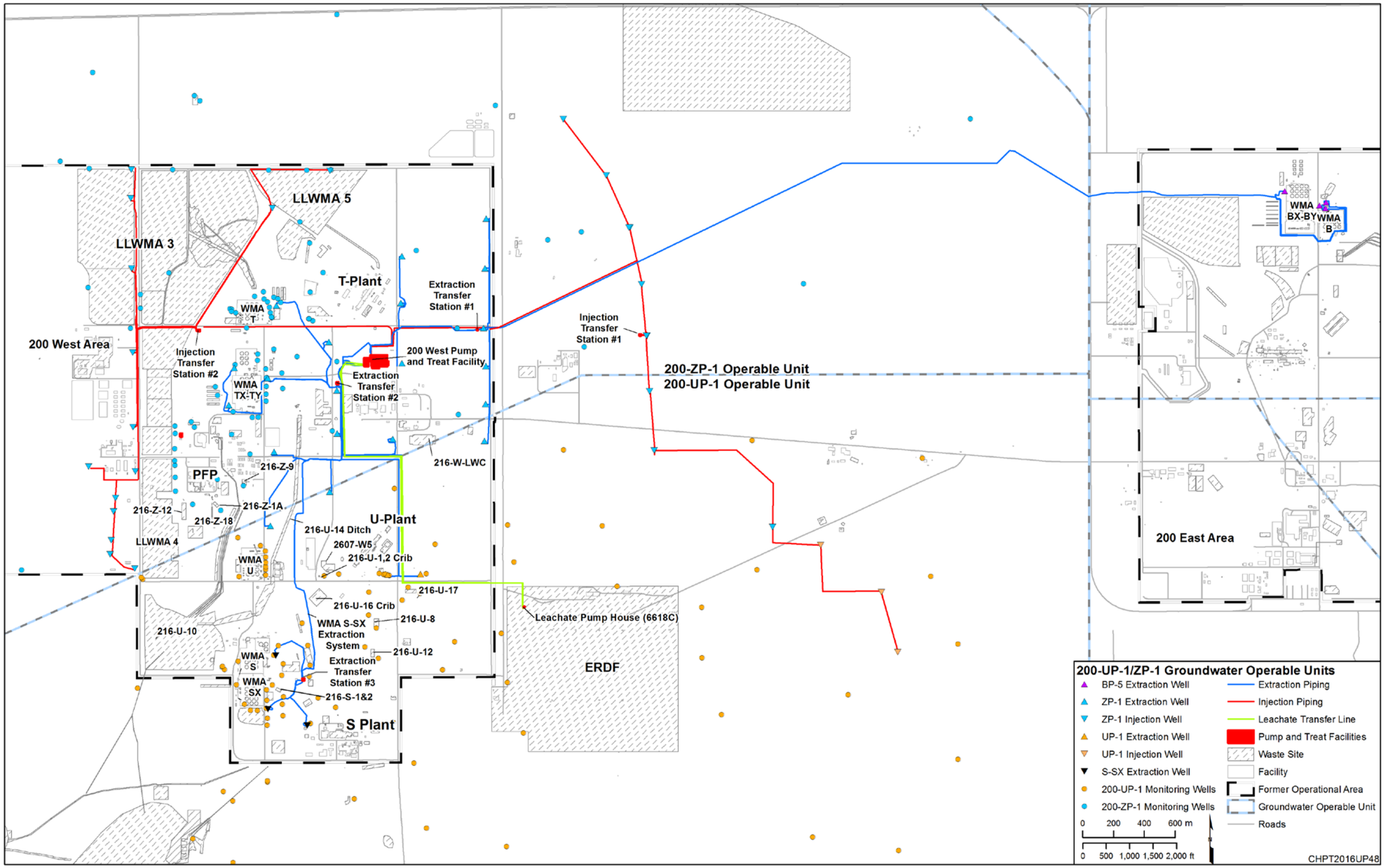

ERDF = Environmental Restoration Disposal Facility LLWMA = low-level waste management area PFP = Plutonium Finishing Plant

Figure 1-1. Hanford Site 200 West Area, Groundwater OUs, and Associated Waste Sites

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In 2016, the 200 West P&T also received extracted groundwater from the 200-DV-1 OU, 200-BP-5 OU and ERDF leachate for treatment. Extracted groundwater from the 200-DV-1 OU and 200-BP-5 OU includes perched water in the deep vadose zone and groundwater from the unconfined aquifer, respectively, from the B Complex Area located in the 200 East Area. Extracted groundwater from 200-BP-5 is transferred via pipeline to the 200 West P&T. Perched groundwater extracted from the 200-DV-1 OU was transferred by truck to an offload system inlet tank at the 200 West P&T. In 2016, construction began to connect the 200-DV-1 perched water extraction wells to the 200-BP-5 OU groundwater pipeline for transfer to the 200 West P&T. Construction was completed in 2016 to install a transfer line for ERDF leachate to the 200 West P&T.

Chapter 2 documents performance of the 200 West P&T operations. Chapter 3 documents performance of the 200-UP-1 remedy, which includes the WMA S-SX groundwater extraction system, U Plant area P&T, and iodine-129 hydraulic containment components of the 200-UP-1 remedy, and Chapter 4 describes performance of the 200 West P&T related to the 200-ZP-1 groundwater remedy objectives. Performance of the 200-DV-1 and 200-BP-5 groundwater extraction systems are presented in Chapters 5 and 6, respectively. The following information is presented in Chapters 2 through 6:

- Activities and developments during 2016
- Summary of extraction well data (including extraction flow rates)
- Treatment system performance (including mass removed and volume treated)
- Trends for COCs in extraction and key monitoring wells
- Groundwater plumes
- Conclusions on 2016 remedy performance

Additional information on the nature and extent of groundwater contamination is presented in DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*. Appendix E of DOE/RL-2016-67 provides a discussion of quality assurance (QA) and quality control (QC) as applied to groundwater sampling and analysis during 2016.

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2 200 West Pump and Treat Remedial System Operation

This chapter discusses the remedial system operational activities associated with the 200 West P&T system during 2016. The 200 West P&T was initially designed to remove carbon tetrachloride, total chromium and hexavalent chromium, nitrate, technetium-99, trichloroethene (TCE), and low concentrations of iodine-129. A new IX train for removing uranium was installed in 2015. Treatment systems include IX, anoxic and aerobic bioreactors, and air stripping. Operation of the 200 West P&T system for groundwater remediation is important in achieving the remedial action objectives (RAOs) for returning the 200-ZP-1 OU groundwater to beneficial use as a potential drinking water source and protecting the Columbia River and its ecological resources from degradation and unacceptable impact caused by the OU contaminants treated by the 200 West P&T system.

Operation of the 200 West P&T (Figure 2-1) began in 2012 initially treating contaminated water from the 200-ZP-1 OU and from WMA S-SX in the 200-UP-1 OU. With the installation of an IX system specifically designed to remove uranium-contaminated water, treatment of uranium- and technetium-99-contaminated water began for the 200-UP-1, 200-DV-1, and 200-BP-5 OUs, and ERDF leachate. A detailed description of the 200-UP-1 OU remedial action is found in Chapter 3. Details regarding ERDF can be found in EPA, 1995, *Record of Decision: U.S. DOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*; and EPA/ESD/R10-96/145, 1996, *Explanation of Significant Differences: USDOE Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*.

Figure 2-1. Aerial Photograph of the 200 West P&T

Activities performed during 2016 included the connection and continued operation of one extraction well in the 200-BP-5 OU, the hydraulic testing of three perched water wells, and the connection of these perched water wells to the 200 West P&T from the 200-DV-1 OU. Details of the 200-ZP-1 OU remedial actions are discussed further in Chapter 4. Details of the perched water removal action activities and the hydraulic testing performed in 2016 are discussed in Chapter 5. A description of the 200-BP-5 groundwater extraction is found in DOE/RL-2015-75, *Aquifer Treatability Test Report for the 200-BP-5 Groundwater Operable Unit*, and presented in Chapter 6.

2.1 200 West Pump and Treat Remedial System Overview

This section provides a brief description of the 200 West P&T, flow rates, and the data collected to monitor performance. Data collection associated with operation of the 200 West P&T began in July 2012, following facility startup. Decisions regarding optimization and system performance (in order to meet RAOs) are made based on an evaluation of the data against the decision statements (DSs) presented in the 200-ZP-1 performance monitoring plan (PMP; DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*). Table 2-1 lists the 200 West P&T performance parameters for 2016.

Table 2-1. 200 West P&T Performance for 2016

Performance	2016	Since 2012 [a]
Total Groundwater Processed (L)	3,038,729,850	13,383,421,760
Mass removed		
Carbon tetrachloride (kg)	1,721	10,985
Chromium (total and hexavalent; kg)	69.7	319.6
Iodine-129 [b] (pCi)	0.0	242,010,000
Nitrate (as NO_3; kg)	330,877	1,174,990
Technetium-99 (g)	147	432
Trichloroethene (kg)	8.6	47.5
Uranium [c] (kg)	33.3	42.2
Average mass removal efficiency [d]		
Carbon tetrachloride	99.9%	99.8%
Chromium (total and hexavalent)	80.8%	82.4%
Iodine-129 [b]	0.0%	14.1%
Nitrate (as NO_3)	80.9%	72.5%
Technetium-99	96.3%	96.3%
Trichloroethene	91.1%	86.7%
Uranium [c]	97.9%	97.7%
System availability [e]	>90%	>90%
Plume area at 2,000 µg/L (km^2)	0.68	0.29 [f]

a. 200 West P&T began operations in July 2012.

b. In 2016, iodine-129 concentrations were below detection (<0.6 pCi/L) in the influent and effluent.

c. Uranium is included to track treated 200-UP-1 OU and 200-BP-5 OU groundwater.

d. Mass removal efficiency = [(influent – effluent) ÷ (influent)] × 100.

e. System availability = [(total time online) ÷ (total possible run time)].

f. Represents area calculated for 2012.

2.1.1 200 West Pump and Treat Remedial System Components

The 200 West P&T system includes seven primary system components: (1) radiological pre-treatment, (2) biological groundwater treatment, (3) sludge handling, (4) sludge stabilization, (5) chemical feed system, (6) air stripping, and (7) off-gas treatment. The major components for each of the systems are as follows:

- The radiological pre-treatment system, which includes technetium-99 and uranium IX
- The biological groundwater treatment system, which includes anoxic/anaerobic biodegradation in a fluidized bed reactor (FBR) and aerobic biodegradation/membrane filtration
- The sludge handling system, which includes rotary drum thickeners, aerated sludge holding tanks, dewatering in centrifuges, and centrate return system
- The sludge stabilization system, which includes lime silos, pug mills, conveyors, and screw conveyors
- The chemical feed system, which includes finished water chemistry adjustments through chemical addition
- The air-stripping system, which include packed tower air strippers and demisters
- The off-gas treatment system, which includes the capture of the air-stripper and tank off-gas emissions through vapor-phase granular-activated carbon (GAC)

The 200 West P&T includes two separate buildings to conduct water treatment. The radiological building contains three IX trains. One IX train, with a nominal flow capacity of 1,136 L/min (300 gpm) (1,515 L/min [400 gpm] max) installed in 2015, treats uranium-contaminated water from the 200-UP-1, 200-DV-1, and 200-BP-5 OUs. Two IX trains remove technetium-99 and limited removal of low concentrations of iodine-129 (near 1 pCi/L) in contaminated water from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs at a nominal flow capacity of 2,271 L/min (600 gpm). If necessary, the influent pH is adjusted to improve IX resin performance. Additional IX treatment trains can be added in the future to increase the flow capacity or treat other radiological COCs. The radiological building only accepts contaminated water with elevated uranium and technetium-99 concentrations. Uranium- and technetium-99-contaminated water initially fills an influent tank, is pumped through particulate filters (to remove suspended materials), and passes through an IX treatment train of three columns in series containing DOWEX® 21K resin. This resin has proven effective in removing uranium. Once treated to remove uranium, the water flows to another influent tank and is blended with water contaminated with technetium-99 and low concentrations of uranium from the 200-UP-1 and 200-ZP-1 OUs (1 to 3 µg/L background concentrations). The blended water is pumped through particulate filters (to remove suspended materials) and passes through two parallel IX treatment trains containing Purolite® A530E resin. This resin removes technetium-99 and also provides limited removal of iodine-129 at low concentrations (near 1.0 pCi/L). The water is then transferred to the biological treatment building for further treatment. When the lead vessel in each of the IX treatment trains becomes fully loaded, the resin is transferred to a separate tank where it is heated to 71°C (160°F) to remove volatile organic compounds (VOCs) prior to disposal at ERDF.

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The biological treatment building has a maximum flow capacity of 9,500 L/min (2,500 gpm), with a sustained nominal flow of 7,571 L/min (2,000 gpm) when recirculation and downtime for operational and maintenance activities are included. Groundwater from the extraction wells without radiological content and treated water from the radiological building is initially pumped into an equalization tank and then into two parallel FBRs. The FBRs contain carbon substrate in suspension for micro-organisms to populate, to supply a carbon-based food source for the microbes to eat (e.g., MicroCg,® molasses, or sodium lactate), and to allow nitrogen in nitrate for the microbes to breathe (represents anoxic conditions that contain little or no dissolved oxygen). FBRs are maintained at a temperature between 13°C and 32°C (55°F and 90°F), and pH is between 6.5 and 6.8 to maximize microbial growth. Microbes in the FBRs break down the nitrate and as much as 50% of the carbon tetrachloride and TCE. Anoxic conditions in the FBRs also reduce hexavalent chromium to trivalent chromium.

From the FBRs, water is pumped through a carbon separation tank, then through a splitter box that divides the water evenly between four membrane bioreactors (MBRs) that further break down the contaminants. MBRs use submerged membranes for filtration. Vertically strung fibers are found in the membrane zone, where a vacuum draws water through tiny pores in the fibers. The liquid is then pumped to air strippers to remove any VOCs that have passed through the bioreactors. Solids from the MBRs are pumped to rotary drum thickeners and centrifuges for dewatering prior to lime being added to kill the bacteria, control odor, and dry the sludge. The conditioned sludge is disposed at ERDF and the final treated water is pumped to the injection well field. Figure 2-2 depicts the entire project, including the pipelines. Figure 2-3 illustrates the various components and pathways of the 200 West P&T.

Overviews of each of the system components and operation during 2016 are provided in the following subsections.

2.1.1.1 Radiological Pre-Treatment

Radiologically contaminated groundwater extracted from wells targeting technetium-99 and uranium plumes in the 200-ZP-1 OU, 200-UP-1, 200-BP-5, 200 DV-1 OUs, and collected leachate from ERDF, is transferred to the radiological treatment (Figure 2-3). At the radiological treatment building the influent is treated through IX trains to reduce concentrations to less than 30 µg/L for uranium and 900 pCi/L for technetium-99. Influent groundwater is filtered to remove the fine particulate matter prior to flowing through the IX trains and then passes through a final set of filters to transfer to the main process building. Groundwater treated through the radiological treatment building is then transferred to the main treatment process building.

During 2016 the IX resin trains operated at their designed nominal flow rates of 1,136 L/min (300 gpm) and 2,271 L/min (600 gpm). In November 2016, resin in the technetium-99 IX column was changed out for the first time since the start of operations. The spent resin was transferred to the resin strip tank (Figure 2-3) for heating to remove carbon tetrachloride.

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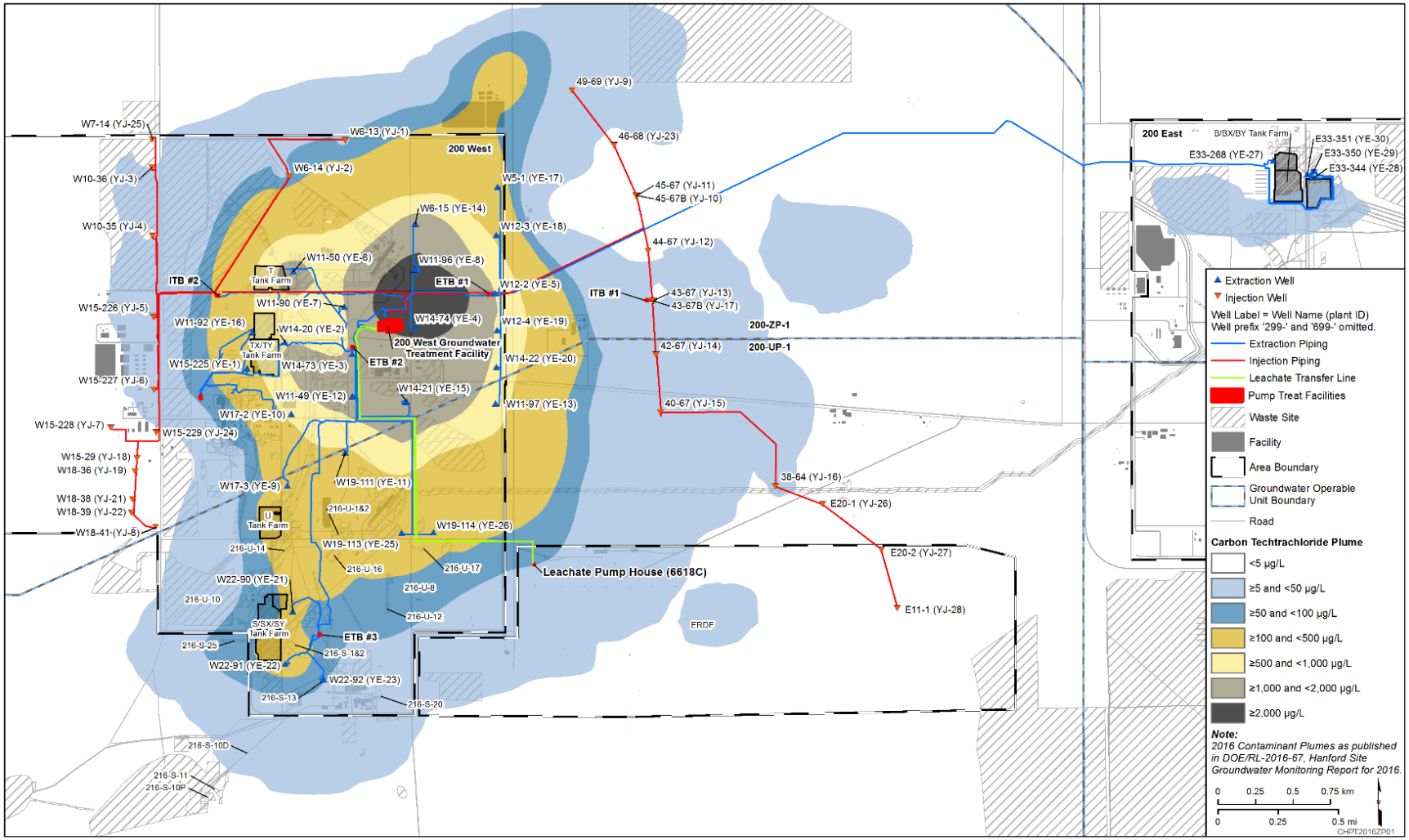

Figure 2-2. 200 West P&T with Project Components, Well Locations, and Piping Routes

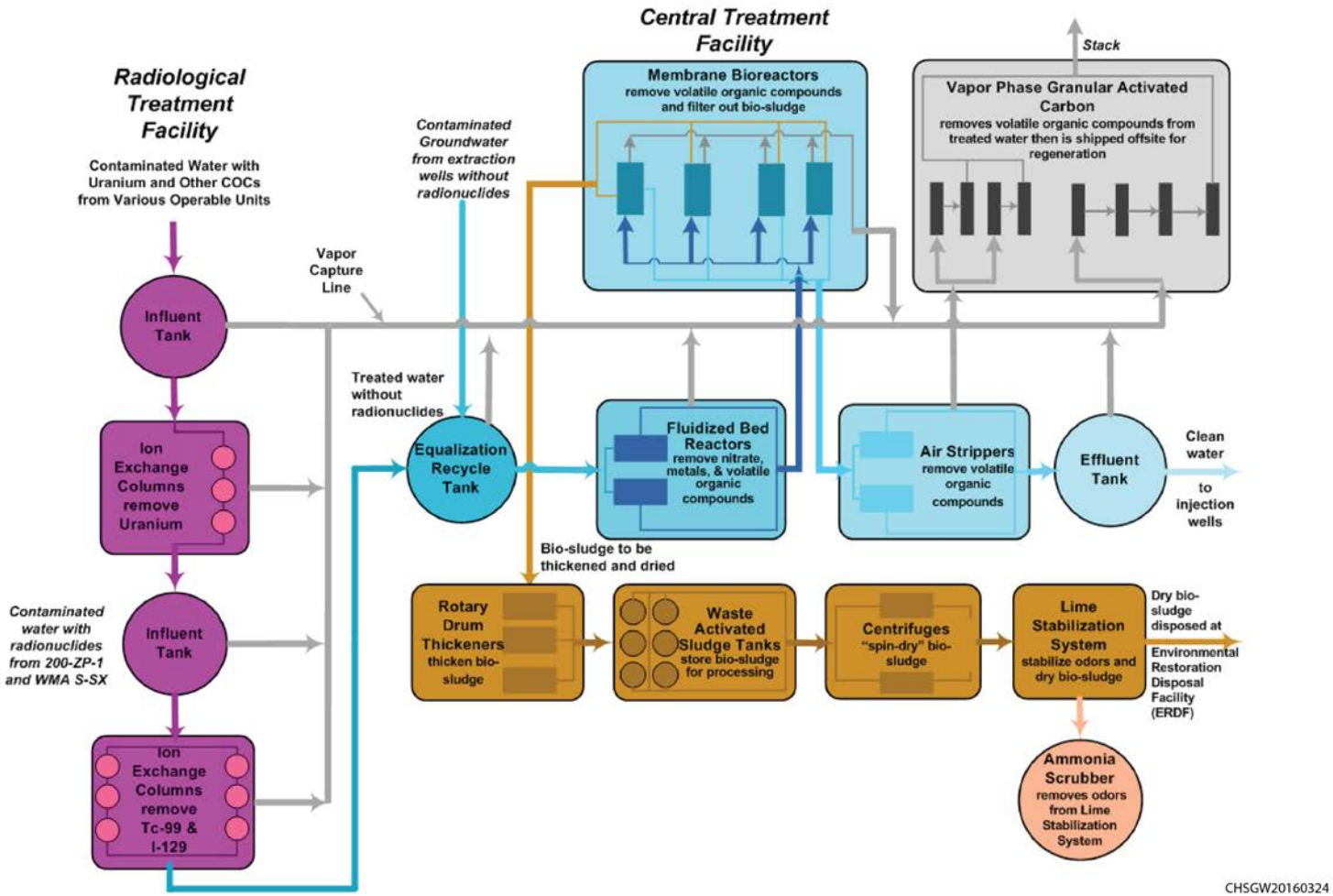

Figure 2-3. 200 West P&T Treatment Process

2.1.1.2 Biological Groundwater Treatment System

The biological groundwater treatment system is designed to remove carbon tetrachloride and nitrate configured in two parallel 4,730 L/min (1,250 gpm) treatment trains to accommodate a maximum instantaneous flow of 9,460 L/min (2,500 gpm). The biological treatment building has a nominal sustained flow of 7,571 L/min (2,000 gpm). The value for sustained capacity includes allowances for recycle streams and downtimes for operation and maintenance activities. The treatment facility infrastructure is designed to accommodate a third treatment train, if required, to enable a maximum instantaneous flow of 14,200 L/min (3,750 gpm).

In 2016 improvements were made to the MBRs to allow for higher system flowthrough and less downtime for maintenance. The membranes in the MBRs act as filters to remove solids before the treated water passes through the air-tripper towers. A buildup of pressure downgradient of each MBR indicates clogging and requires cleaning of the membranes. Taking an MBR offline for cleaning reduces system flow-through by 2,300 L/min (600 gpm). To increase the time between cleanings, a cassette was added to each MBR. Because membranes wear out over time, new membranes in aerated membrane tank D (AMT-D) were installed, the first of planned staggered membrane replacements to ensure that all membranes do not wear out at the same time. Also in 2016, MBR A (one of four) was upgraded with new technology that is more reliable and uses less energy.

New cassettes were installed in AMT-D (Figure 2-3). All of the cassettes were removed and cleaned for AMT-A, AMT-B, and AMT-C. Cassettes were increased from five to six per AMT, increasing the capacity of the AMTs. This work was initiated in April 2016 and installation completed in May 2016. The operational testing was completed in June 2016.

A leak in FBR-A was identified on March 21, 2016; by March 31, carbon media was intermittently discharged from the leak onto the concrete pad and FBR-A was removed from service. In June FBR-A repairs were completed and FBR-A carbon was loaded and was placed back in service by June 28, 2016. In July, flows through FBR-A were slowly increased and nitrate levels were monitored as the bacteria population increased to grow on the carbon.

2.1.1.3 Sludge Handling

Solids from the MBRs are pumped to rotary drum thickeners and centrifuges for dewatering prior to lime being added to kill the bacteria, control odor, and dry the sludge. The conditioned sludge is then disposed at ERDF. In 2015 the 200 West P&T consolidated the bio-solids and debris generated from the process systems for handing in roll-off boxes for shipment to ERDF. Sludge handling during 2016 operated within design parameters with no issues, generating 1,890 m^3 (66,744 ft^3) of consolidated waste. In 2016, 126 roll-off boxes (15 m^3 per roll-off box) from the 200 West P&T were shipped to ERDF. Four active GAC canisters were changed out in 2016 and shipped to the regeneration/disposal facility in Arizona.

2.1.1.4 Sludge Stabilization

The treatment of nitrate results in the biological sludge that is disposed of at ERDF. The sludge material must be free of liquids and must pass the paint filter test to meet ERDF disposal criteria. It must also be stabilized to minimize biological breakdown and control order. A screw conveyor is used to move the dewatered sludge from the centrifuge to the lime sludge stabilization system where a mechanical mixer (pug mill) performs the mixing. During 2016, the sludge stabilization system performed to design capacity and the combined bio-solids and debris were managed and shipped to ERDF.

2.1.1.5 Air-Stripping System

The treated water from the membranes is pumped to an air stripper (Figure 2-3) for removal of the remaining carbon tetrachloride and other VOCs. The air-stripper effluent is then pumped to an effluent tank. Acid is added upstream of the effluent tank through an inline static mixer to adjust the pH.

The air-stripper tower is piped so this treatment step can occur before the FBR in the event degradation of the carbon tetrachloride in the FBR is less than anticipated. For the later scenario, water from the influent equalization tank is pumped through a strainer to remove larger particles before entering the air strippers. Process monitoring was conducted during the initial operations to determine the optimum air-stripper configuration. During 2016, the air-stripper optimized configuration was maintained. The stripper tower citric acid cleaning commenced in October and was completed in early November 2016 for both towers.

2.1.1.6 Off-Gas Treatment System

Off-gas from the air stripper, influent equalization tank, radiological building strip tanks (technetium-99 and uranium), FBRs, membrane tanks, sludge holding tanks, rotary drum, and centrifuges is combined and treated by vapor-phase GAC. To avoid buildup of radionuclides in the vapor-phase GAC, air streams to the vapor-phase GAC system were pre-treated by a demister to minimize liquid carryover. During 2016, the vapor-phase GAC system operated as designed with the changeout of four GACs, thereby maintaining operations of this system and minimizing any buildup of carbon tetrachloride or radionuclides.

2.1.1.7 Reliability and Redundancy Provisions

To achieve the cleanup goals, reliability and redundancy provisions have been included in the design of the 200 West P&T (DOE/RL-2010-13, *200 West Area Groundwater Pump-and-Treat Design Report*). These provisions are in place to ensure that the system has operational flexibility to continue operations during routine and preventive maintenance activities as well as backup provisions in case of unscheduled maintenance or equipment failure. The reliability and redundancy provisions were maintained during 2016.

Additional improvements to the facility to increase system reliability included the following:

- New platforms were installed around the top of the aerated sludge holding tanks and centrate tanks with construction finishing in August 2016.
- New platforms were installed around the top of the Fluidized Bed Reactors and Carbon Separator tanks, with construction concluding in August 2016.
- Major portions of polyvinyl chloride (PVC) piping in injection transfer building 2 (ITB-2) were replaced with stainless steel in October and completed in November 2016.
- Stainless steel conversion of facility extraction well piping was completed, which decreases the potential for leaks.

2.1.2 Extraction and Injection Well Network

The 200 West P&T extraction and injection well network is designed for hydraulic containment and recovery of groundwater contaminants within the 200-ZP-1 and 200-UP-1 OUs. In addition, extracted perched water from the 200-DV-1 OU and groundwater from the 200-BP-5 OU is routed to the 200 West P&T. The new 200-ZP-1 and 200-UP-1 extraction wells installed in 2016 are 20 cm (8 in.) in diameter with long screens (greater than 30 m [100 ft]) placed to within 3 m (10 ft) of the bottom of each well. The 200-BP-5 extraction well connected to the 200 West P&T in 2016 is 20 cm (8 in.) in diameter and screened across the 2.2 m (7.5 ft) unconfined aquifer. Extraction well screens in the 200-ZP-1 OU target intervals with carbon tetrachloride concentrations greater than 100 µg/L. Extraction well screens in the 200-UP-1 and 200-BP-5 OUs target intervals with uranium concentrations greater than 30 µg/L and technetium-99 concentrations greater than 900 pCi/L, respectively.

2.2 200 West Pump and Treat Operational Performance

This section discusses the flow rates of injection and extraction wells, sampling data, and the analysis of the remedial system monitoring data during 2016, and briefly summarizes the overall remedial system.

2.2.1 Extraction and Injection Well Flow Rates

The 200 West P&T extraction system pumped 3.0 billion L (0.8 billion gal) of water in 2016, and the total since July 2012 is 13.4 billion L (3.5 billion gal). Extraction wells in the 200-ZP-1 OU are designed to produce between 303 and 490 L/min (80 and 130 gpm). Injection wells are designed to have an injection capacity of 570 L/min (150 gpm). During 2016, extraction wells performed according to design except wells 299-W6-15, 299-W12-3, and 299-W14-21, which were offline during most of 2016 for maintenance. All three wells had well pump issues and were not repaired before freezing temperatures arrived. The average combined pumping rate from the extraction wells in 2016 was 5,847 L/min (1,544 gpm). The average flow rate by extraction and injection well is summarized in Tables 2-2, and 2-3, respectively, including total run-time percentage (total flow hours divided by total possible run time) for each extraction and injection well currently in use for the 200 West P&T. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping. During 2016, some wells were subject to downtime due to equipment repair and/or maintenance. Figures 2-4 through 2-7 present the 2016 monthly average pumping rate for extraction and injection wells.

Decreased injection well capacity first identified in 2013 (DOE/RL-2014-26, *Calendar Year 2013 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*) as a result of biofouling from the FBRs continued through 2016. Biofouling of the injection wells was caused by the production of a slimy biomass by the microorganisms in the FBRs, which is a stress response to an insufficient nutrient supply. The FBR effluent contains biological micronutrients, particularly manganese, and other particles (e.g., iron oxide, manganese oxides, micro-organisms, and extracellular material) precipitated from the biological treatment process. The micronutrients and precipitation particles result in an injected water stream that has caused biological and particle fouling and plugging in the 200 West P&T injection wells. Chemical dosing of micronutrient and carbon substrate feed to the biological treatment system has been optimized to balance biological needs within the plant while minimizing the release of substances that might foul the wells. However, thorough removal of biofouling and mineral deposits within the wells is difficult, requiring multiple cleanings of each injection well to restore injection capacity, and drilling of new injection wells as necessary. Flows through the system in 2016 were reduced even further as injection wells were taken offline and cleaned to remove the clogging material and change out to stainless steel piping in the injection transfer building 2.

Table 2-2. Flow Rates and Total Run Times for 200 West P&T Extraction Wells, 2016

Well ID	Well Name	PLC ID	Average Flow Rate, L/min (gpm)	Total Flow Hours in 2016	Total Run Time (%) *	Purpose
C7017	299-W15-225	YE01B	304.9 (80.5)	7920	90.2	200-ZP-1 Extraction
C7018	299-W14-20	YE02B	400.4 (105.7)	8616	98.1	
C7021	299-W14-73	YE03B	345.5 (91.2)	7920	90.2	
C7024	299-W14-74	YE04	366.6 (96.8)	6432	73.2	
C7027	299-W12-2	YE05B	331.3 (87.5)	5808	66.1	
C7020	299-W11-50	YE06B	321.9 (85)	7824	89.1	
C7022	299-W11-90	YE07B	381.3 (100.7)	8664	98.6	
C7754	299-W11-96	YE08	344.8 (91)	5304	60.4	
C7577	299-W17-3	YE09B	323.8 (85.5)	7392	84.2	
C7576	299-W17-2	YE10B	336.1 (88.7)	7104	80.9	
C8718	299-W19-111	YE11B	149.2 (39.4)	336	3.8	
C7019	299-W11-49	YE12B	365.4 (96.5)	7296	83.1	
C8719	299-W11-97	YE13B	269.4 (71.1)	5616	63.9	
C8720	299-W6-15	YE14B	264.6 (69.8)	5136	58.5	
C7494	299-W14-21	YE15B	289.7 (76.5)	1200	13.7	
C7025	299-W11-92	YE16B	338.7 (89.4)	8352	95.1	
C8721	299-W5-1	YE17B	277.5 (73.3)	5544	63.1	
C7028	299-W12-3	YE18B	308.5 (81.5)	5304	60.4	
C7029	299-W12-4	YE19B	328.7 (86.8)	5784	65.8	
C7030	299-W14-22	YE20B	269.7 (71.2)	5544	63.1	
C8095	299-W22-90	YE21B	90.6 (23.9)	6384	72.7	S-SX Extraction
C8096	299-W22-91	YE22B	129 (34.1)	8616	98.1	
C8097	299-W22-92	YE23B	125.8 (33.2)	8688	98.9	
C8927	299-W19-113	YE25B	203 (53.6)	8784	100.0	200-UP-1 Extraction
C8928	299-W19-114	YE26B	368.5 (97.3)	8784	100.0	
C8243	299-E33-268	YE27B	314.9 (83.1)	6936	79.0	200-BP-5 Extraction

* Percentage total run time is calculated by [(days well in operation) ÷ (number of days in the CY)].

ID = identification

PLC = programmable logic controller

Table 2-3. Flow Rates and Total Run-Times for 200 West P&T Injection Wells, 2016

Well ID	Well Name	PLC ID	Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2016	Total Run Time (%) *	Purpose
C8064	299-W6-13	YJ01A	205.4 (54.2)	7008	79.8	200-ZP-1 Injection
C8065	299-W6-14	YJ02A	576.5 (152.2)	7944	90.4	
C8066	299-W10-36	YJ03A	262.7 (69.4)	7824	89.1	
C7573	299-W10-35	YJ04A	339 (89.5)	7464	85.0	
C7574	299-W15-226	YJ05A	653.5 (172.5)	8208	93.4	
C7575	299-W15-227	YJ06A	419.6 (110.8)	8184	93.2	
C8716	299-W15-228	YJ07A	531.7 (140.4)	6624	75.4	
C8920	299-W18-41	YJ08A	348.9 (92.1)	6288	71.6	
C8786	699-49-69	YJ09A	144.5 (38.1)	6768	77.0	
C8717	699-45-67B	YJ10A	9.7 (2.6)	2616	29.8	
C7578	699-45-67	YJ11A	135.3 (35.7)	6792	77.3	
C8068	699-44-67	YJ12A	56.1 (14.8)	3456	39.3	
C7579	699-43-67	YJ13A	0 (0)	0	0.0	
C8069	699-42-67	YJ14A	338 (89.2)	7800	88.8	
C8070	699-40-67	YJ15A	131.3 (34.7)	7968	90.7	
C8921	699-38-64	YJ16A	183.3 (48.4)	8016	91.3	
C8386	699-43-67B	YJ17A	199.5 (52.7)	8040	91.5	
B2409	299-W15-29	YJ18	190.5 (50.3)	7320	83.3	
B2747	299-W18-36	YJ19	261.2 (69)	8016	91.3	
B2757	299-W18-38	YJ21	204.8 (54.1)	7656	87.2	
B2758	299-W18-39	YJ22	65.9 (17.4)	7416	84.4	
C8067	699-46-68	YJ23A	184 (48.6)	8184	93.2	
C8944	299-W15-229	YJ24A	452.6 (119.5)	6048	68.9	
C9521	299-W7-14	YJ25A	739.8 (195.3)	3192	36.3	
C9482	299-E20-1	YJ26	190.1 (50.2)	8016	91.3	I-129 Containment
C9483	299-E20-2	YJ27	174.4 (46)	6528	74.3	
C9484	299-E11-1	YJ28	216.7 (57.2)	8256	94.0	

* Percentage total run time is calculated by [(days well in operation) ÷ (number of days in the CY)].

ID = identification

PLC = programmable logic controller

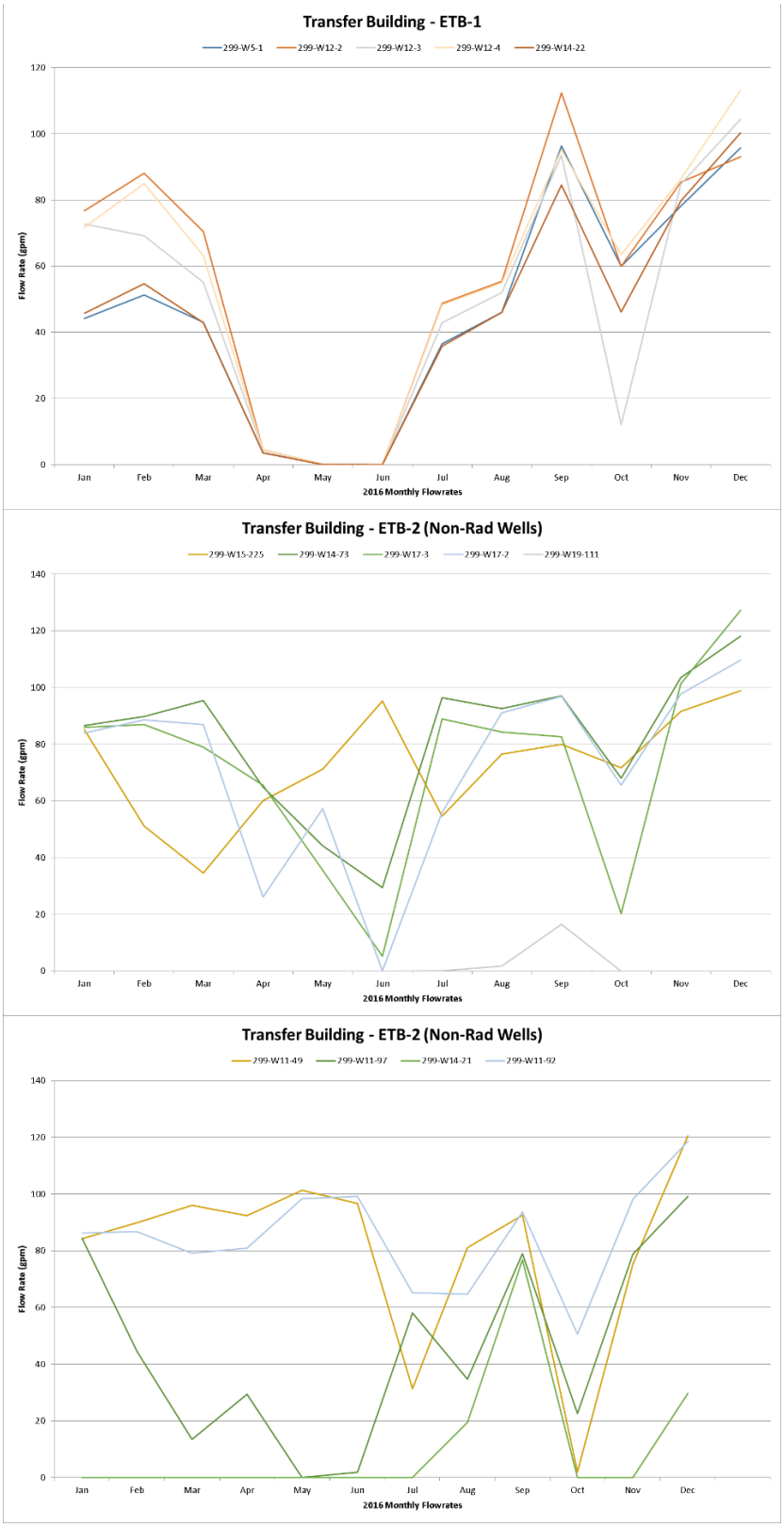

Figure 2-4. 200 West P&T Flow Rates for Extraction Wells without Radiological Contaminants, 2016

Figure 2-5. 200 West P&T Flow Rates for Extraction Wells with Radiological Contaminants, 2016

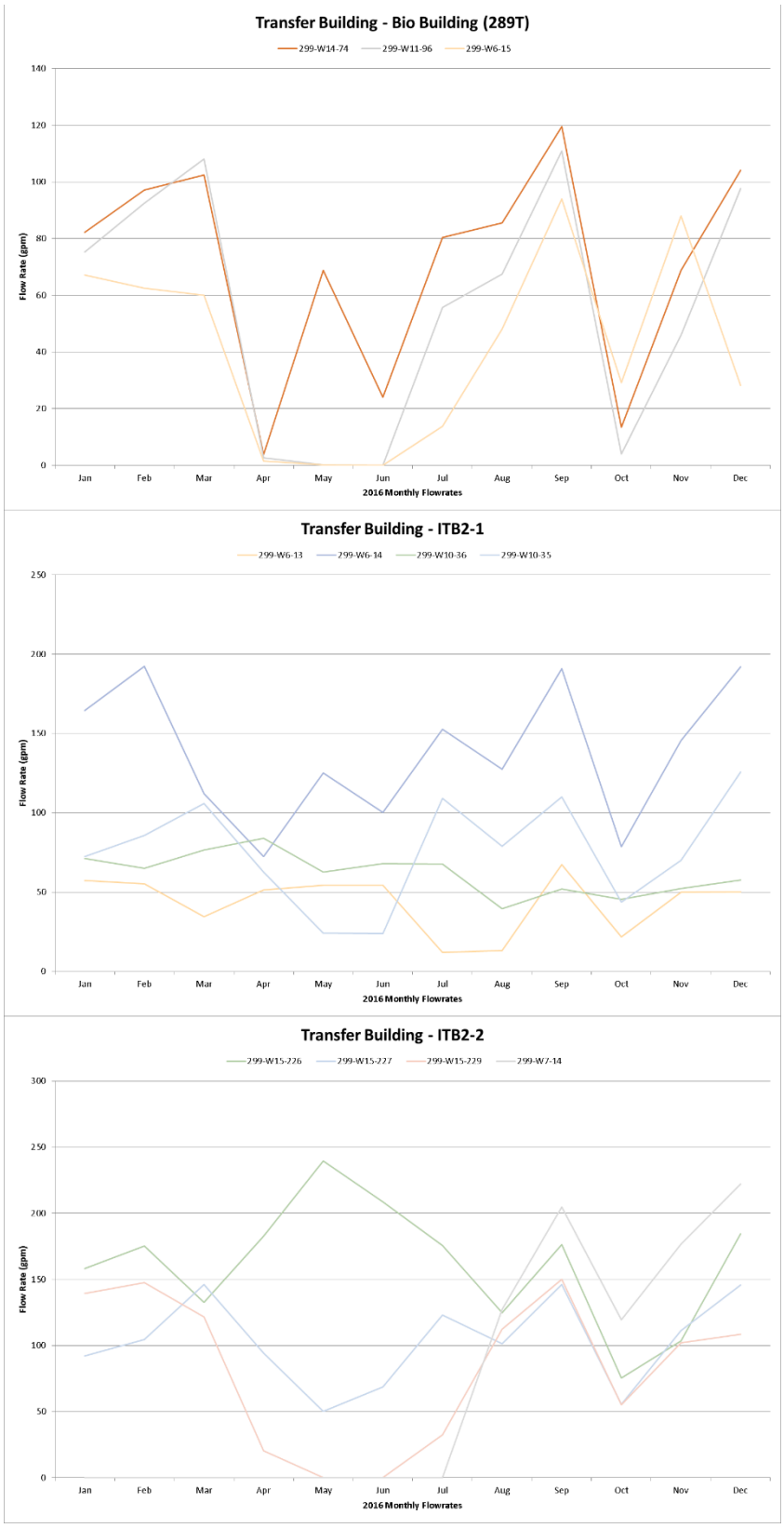

Figure 2-6. 200 West P&T Flow Rates for Extraction Wells without Radiological Contaminants (Top) and for Injection Wells (Middle and Bottom), 2016

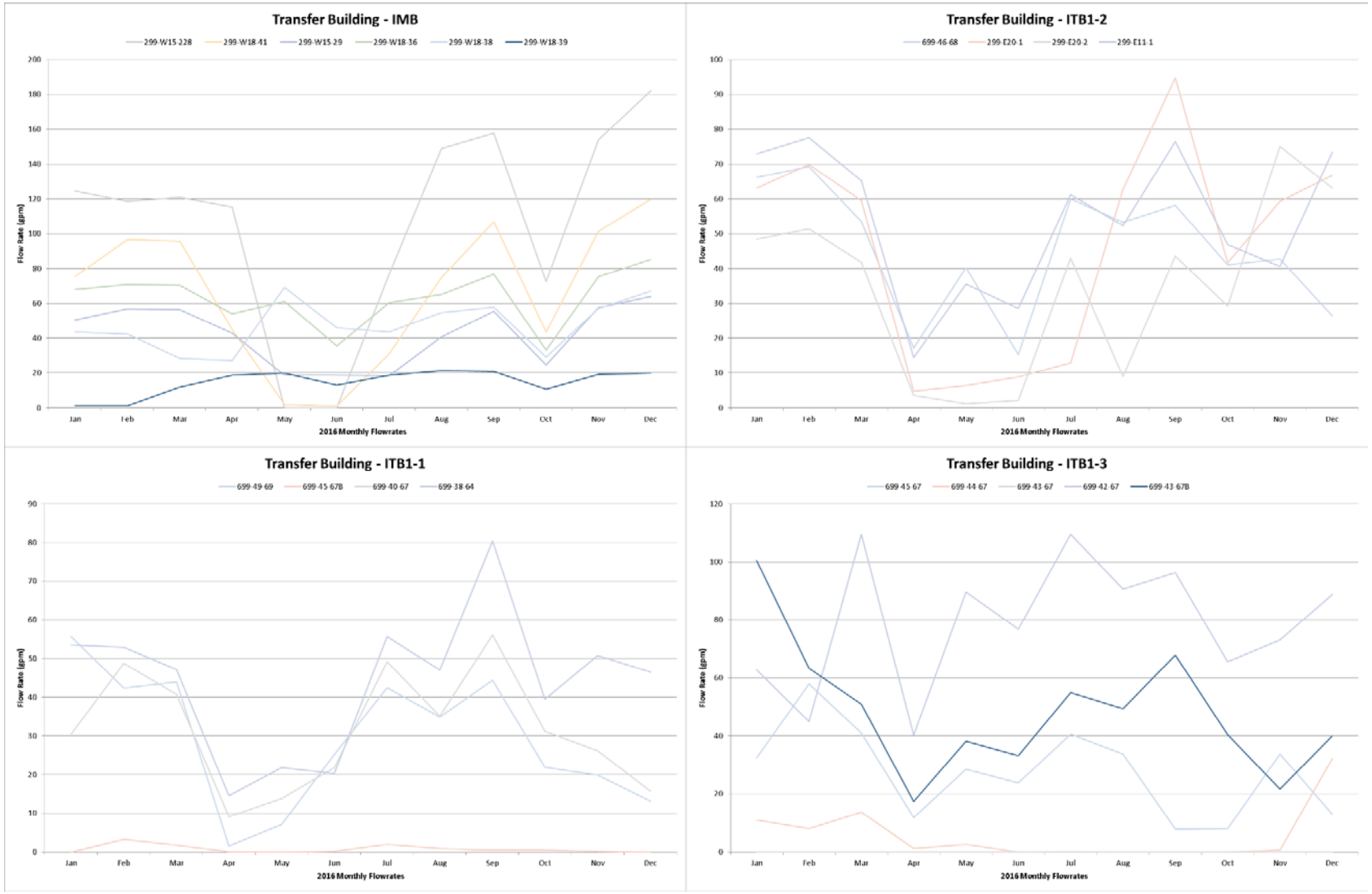

Figure 2-7. 200 West P&T Flow Rates for Injection Wells, 2016

Several studies have been performed or initiated to evaluate minimizing the release of fouling materials as follows:

- One Water Solutions, 2016, *Effluent Technical Review Services Contract No. 60073*
- Envirogen, 2017, *Evaluation Report of 200 West Pump & Treat Fluidized Bed Reactors*
- PNNL, 2017, *200 West Pump-and-Treat Facility Biofouling Assessment*
- SGW-60655, *Surface Infiltration Evaluation Report for the 200 West Pump and Treat Facility,* Draft
- SRNL-STI-2017-0163, *Evaluation of the Hanford 200 West Groundwater Treatment System: Fluidized Bed Bioreactor*

Recommendations from the above studies that are planned for implementation in 2017 include the following:

- Attempt to revive marginal or out-of-service injection wells with more extensive and aggressive cleaning techniques. If successful, additional injection well capacity without drilling more wells may become available for enhanced production rates and may also be sufficient offline test beds for other suggestions (like lower pumping rates) to minimize clogging forces.
- Fabricate injection well screens from a round wire that has a more favorable flow impedance geometry than the present use of triangular wire (i.e., more resistant to clogging).
- Use a metered pump to add well development water gradually back into the P&T plant versus the present method of dumping it in all at once. This method avoids large spikes in contaminants (e.g., manganese) and prevents episodic distortion of the incoming water chemistry.
- Engineer, fabricate, and place in trial pair of aboveground switchable screening segments just before the connection to injection well pumping, where these screen segments duplicate the injection well screen configuration and flow characteristics (the team noted that other filter/screen designs and approaches may be more effective overall). This process should remove most clogging materials because they are caught by this cleanable screen before entering and clogging the well screen.

2.2.2 Extraction Well Sampling Data

Extraction wells are sampled quarterly, and samples are analyzed for all COCs and natural attenuation products. The average concentrations of COCs for 2016 (January through December) are presented in Table 2-4. Chapter 4, Section 4.3 discusses the COC data from the extraction and monitoring wells.

2.2.3 Treatment Plant Influent and Effluent Flow Rates

For 2016, the 200 West P&T operated at an average flow rate from 26 extraction wells of 6,044 L/min (1,597 gpm). Table 2-5 shows the volume of groundwater processed and average calculated flow rate through the 200 West P&T. Flow through the system varied between 3,610 and 8,191 L/min (954 and 2,164 gpm) in 2016. Flows were reduced from April through June for repairs to a leak in FBR A and again in October for cleaning of the air-stripper towers as described in Section 2.1.1. The downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for each extraction well. The monthly online availability for the 200 West P&T system for 2016 is shown in Figure 2-8.

Table 2-4. Extraction Well Average Concentration, 2016

Well Name	Programmable Logic Controller Identification	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium [a] (µg/L)
299-W15-225	YE-1	180.0	3.0	3.2	<-0.1	38275.0	39.8	0.4	412.0	0.9
299-W14-20	YE-2	1032.0	21.4	23.6	<0	150400.0	1129.2	4.0	2610.0	1.2
299-W14-73	YE-3	930.0	4.8	5.4	<0.2	88500.0	112.0	5.7	1510.0	0.9
299-W14-74	YE-4	720.0	25.7	27.0	<0.3	104666.7	97.7	4.2	4610.0	1.3
299-W12-2	YE-5	914.0	22.7	25.7	<0.1	79700.0	51.8	2.7	249.0	1.2
299-W11-50	YE-6	464.0	41.4	46.6	<0.1	151600.0	1136.8	3.2	2854.0	1.2
299-W11-90	YE-7	1275.0	75.3	85.3	<0.2	258000.0	529.0	10.9	12625.0	1.8
299-W11-96	YE-8	936.7	69.7	74.7	0.9	284666.7	258.3	6.7	10076.7	1.6
299-W17-3	YE-9	270.0	3.0	2.9	<0	38075.0	173.0	1.0	402.5	0.8
299-W17-2	YE-10	796.7	4.8	5.3	<0.2	102000.0	88.8	4.8	<262.3	0.8
299-W19-111	YE-11	330.0	7.3	1.8	<0.1	4870.0	<2.9	1.8	<11.2	0.7
299-W11-49	YE-12	737.5	2.0	2.1	<-0.1	33075.0	88.5	5.2	<86.8	0.8
299-W11-97	YE-13	160.0	2.0	2.1	<0.2	38233.3	<1.6	1.5	<21.5	1.7
299-W6-15	YE-14	1323.3	95.3	109.0	0.7	395333.3	266.0	5.9	6863.3	1.5
299-W14-21 [b]	YE-15	--	--	--	--	--	--	--	--	--
299-W11-92	YE-16	426.7	3.4	4.1	<-0.2	34100.0	24.8	0.8	391.0	0.8
299-W5-1	YE-17	220.0	36.3	42.7	<0.3	223500.0	374.0	0.5	1356.7	1.6

Table 2-4. Extraction Well Average Concentration, 2016

Well Name	Programmable Logic Controller Identification	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium [a] (µg/L)
299-W12-3	YE-18	454.8	34.5	42.0	0.6	220250.0	243.0	1.2	985.8	1.6
299-W12-4	YE-19	672.5	27.8	28.8	<0	30850.0	<1.03625	2.5	<50.9	1.2
299-W14-22	YE-20	333.3	5.3	6.6	<0.1	28300.0	<0.1	2.0	<136.4	1.3
299-W22-90	YE-21	78.5	32.3	37.0	<0.1	26025.0	590.0	0.3	1143.3	2.7
299-W22-91	YE-22	63.3	30.3	35.0	<0.1	30450.0	3150.0	<0.3	5140.0	2.7
299-W22-92	YE-23	68.3	28.0	32.0	0.7	31550.0	2262.5	<0.5	5997.5	4.1
299-W19-113	YE-25	99.5	2.2	2.3	0.8	298750.0	3757.5	1.6	2845.0	44.8
299-W19-114	YE-26	70.8	4.2	2.8	0.6	95125.0	426.3	2.2	538.7	26.8
299-E33-268	YE-27	<0.2	5.1	6.0	1.5	401750.0	7766.7	<0.3	7852.5	69.5

Note: The less than symbol (<) indicates values less than detection limits.

a. Uranium is included to track treated 200-UP-1 OU and 200-BP-5 OU groundwater.

b. Extraction well 299-W14-21 only operated intermittently so no samples were collected in 2016.

Table 2-5. Total Water Processed in 2016

Month	Water Processed (million L [million gal])	Flow Rate (L/min [gpm])
January	287.0 (75.8)	6,645 (1,755)
February	283.3 (74.8)	6,555 (1,732)
March	282.0 (74.5)	6,528 (1,725)
April	164.4 (43.4)	3,805 (1,005)
May	180.7 (47.7)	4,182 (1,105)
June	155.9 (41.2)	3,610 (954)
July	253.2 (66.9)	5,860 (1,548)
August	265.7 (70.2)	6,150 (1,625)
September	351.2 (92.8)	8,131 (2,148)
October	177.9 (47.0)	4,120 (1,088)
November	283.6 (74.9)	6,564 (1,734)
December	353.9 (93.5)	8,191 (2,164)
	Total: 3,038.7 (0.803)	**Average: 5,862 (1,549)**

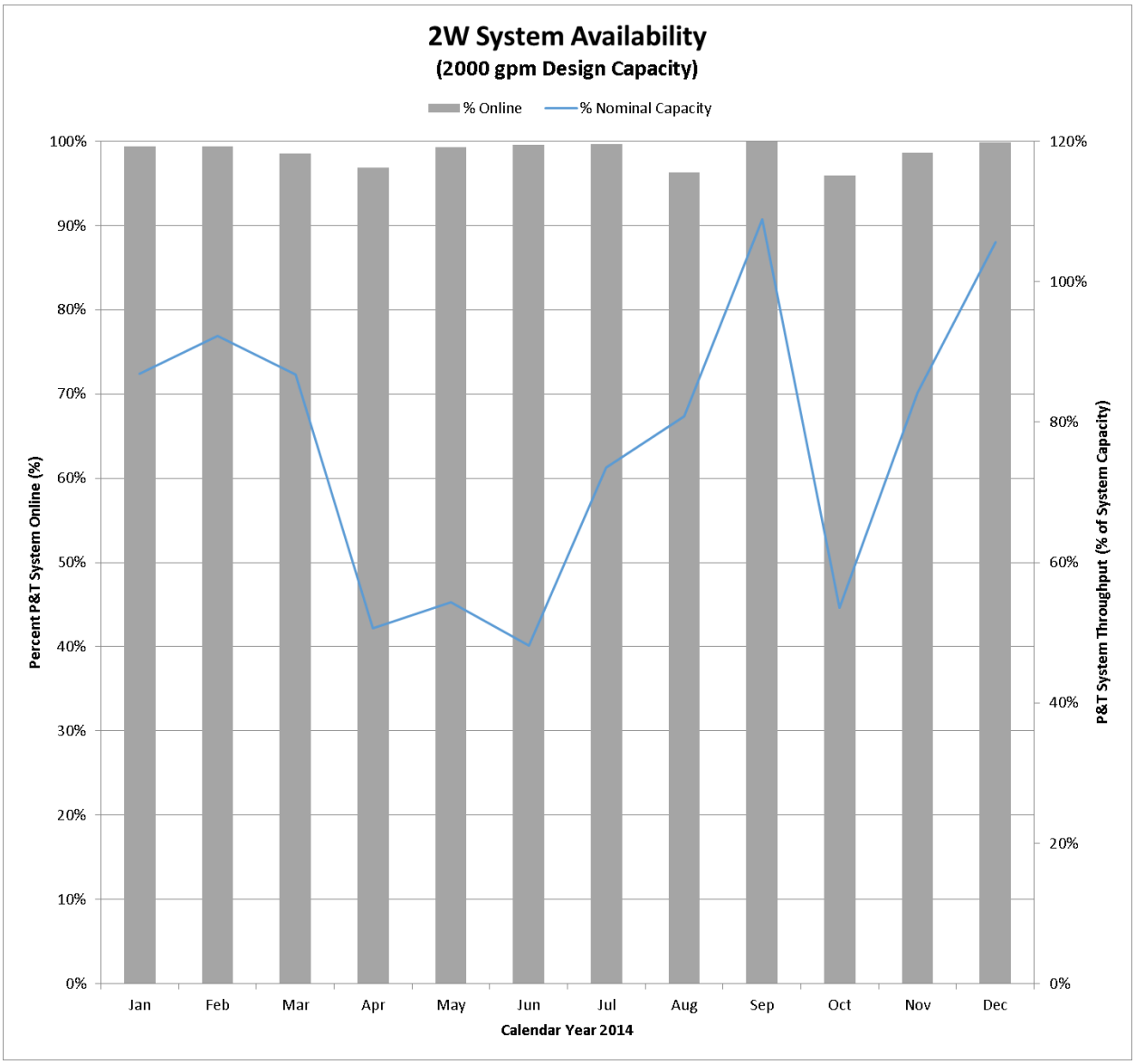

Figure 2-8. Monthly Online Availability for the 200 West P&T, 2016

2.2.4 Treatment Plant Influent and Effluent Sampling Data

Influent and effluent are sampled monthly. The average concentrations of COCs in the influent and effluent for the 200 West P&T from January through December 2016 are presented in Table 2-6.

The concentration of all COCs in the effluent were below the cleanup levels listed in Table 2-6, except for nitrate in the analytical samples collected in November and December. The laboratory sample result for nitrate in the November 30, 2016 sample was 47 mg/L, and the December 29, 2016 sample was 49 mg/L, which are more than the 45 mg/L cleanup value. Process samples collected daily on normal working days to monitoring for transient conditions averaged less than 45 mg/L each month (Table 2-7).

Table 2-6. Central Treatment System Average Influent and Effluent Concentrations for 2016

Month	Cleanup Level – 3.4 Carbon Tetrachloride (µg/L)		Cleanup Level – 100 Total Chromium (µg/L)		Cleanup Level – 48 Hexavalent Chromium (µg/L)		Cleanup Level – 1.0 Iodine-129 [a] (pCi/L)		Cleanup Level – 45 Nitrate as Nitrate (mg/L)		Cleanup Level – 900 Technetium-99 [a] (pCi/L)		Cleanup Level – 1.0 Trichloroethene (µg/L)		Cleanup Level – 20,000 Tritium (pCi/L)		Cleanup Level – 30 Uranium [b] (µg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent [c]	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
January	340	<0.13	15.0	<0.9	17.0	<1.5	0.91	<0.56	128	4	1,100	33	2.4	<0.3	2,930	2,720	45	0.9
February	500	<0.13	26.0	4.1	24.0	3.6	1.05	0.86	150	18	2,000	72	3.4	<0.3	3,560	3,210	43	1.0
March	550	<0.22	25.0	1.3	23.0	<1.5	1.62	<0.79	155	9	2,120	56	3.7	<0.3	4,090	3,560	57	0.9
April	320	<0.13	17.0	2.4	13.0	<1.5	<0.68	<0.75	155	2	2,100	<10	2.4	<0.3	3,850	3,170	42	1.1
May	410	<0.1	18.5	4.3	13.0	5.7	1.92	<0.89	130	35	2,700	52	3.0	<0.3	3,920	4,248	349	1.3
June	310	<0.18	22.5	1.2	22.0	<1.5	<0.79	<0.60	133	44	2,610	68	2.6	<0.3	2,880	2,895	42	0.8
July	390	<0.18	18.5	3.5	17.0	<1.5	1.01	<0.65	128	34	2,280	63	2.8	<0.3	2,230	2,910	44	1.0
August	330	<0.18	23.0	4.2	21.5	5.8	<0.59	<0.82	150	31	2,660	63	2.2	<0.3	3,300	3,240	140	0.8
September	510	<0.18	24.5	4.2	23.5	8.0	<0.67	<0.56	139	15	2,060	92	3.3	<0.3	3,130	3,790	43	0.8
October	380	<0.18	21.0	11.1	21.0	2.5	<0.73	<0.73	124	12	1,550	33	2.8	<0.3	2,600	2,820	27	1.5
November	360	<0.18	25.3	5.1	23.0	8.9	<0.94	<0.90	124	47 [d]	1,590	137	2.9	<0.3	3,140	2,815	110	0.9
December	380	<0.18	20.2	6.3	21.0	6.7	1.36	<0.66	102	49 [d]	1,420	133	2.9	<0.3	2,150	2,390	31	0.9

Note: The less than symbol (<) indicates that the sample result was below the listed detection limit.

a. Iodine-129, technetium-99, and uranium influent concentrations are preresin sample results taken from the radiological treatment system; effluent values are from the biological treatment system.

b. Uranium is included to track 200-UP-1 OU and 200-BP-5 OU groundwater treated.

c. All iodine-129 effluent results were below the listed detection limit except for February results, which were below the cleanup level.

d. Single laboratory sample exceeded the cleanup level; nitrate concentration in the effluent averaged 45 mg/L throughout the month in process samples.

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Table 2-7. Nitrate Process Samples, 2016

Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)
January Average	**4.88**	**21.62**	**February Average**	**4.99**	**22.11**	**March Average**	**4.47**	**19.80**
1/4/2016	4.83	21.39	2/1/2016	7.51	33.26	3/1/2016	5.31	23.52
1/5/2016	2.26	10.01	2/2/2016	7.99	35.38	3/2/2016	6.25	27.68
1/6/2016	2.27	10.05	2/3/2016	4.02	17.80	3/3/2016	4.98	22.05
1/7/2016	2.06	9.12	2/4/2016	4.18	18.51	3/7/2016	7.69	34.06
1/11/2016	1.41	6.24	2/8/2016	3.67	16.25	3/8/2016	1.79	7.93
1/12/2016	2.73	12.09	2/9/2016	3.97	17.58	3/9/2016	4.23	18.73
1/13/2016	5.97	26.44	2/10/2016	3.49	15.46	3/10/2016	5.51	24.40
1/14/2016	6.07	26.88	2/11/2016	4.19	18.56	3/14/2016	2.39	10.58
1/18/2016	7.29	32.28	2/16/2016	6.57	29.10	3/15/2016	2.44	10.81
1/19/2016	9.03	39.99	2/17/2016	3.76	16.65	3/16/2016	5.01	22.19
1/20/2016	7.71	34.14	2/18/2016	8.80	38.97	3/17/2016	5.70	25.24
1/21/2016	6.85	30.34	2/22/2016	0.12	0.51	3/21/2016	4.71	20.86
1/25/2016	4.85	21.48	2/23/2016	3.85	17.05	3/22/2016	3.82	16.92
1/26/2016	4.48	19.84	2/24/2016	3.04	13.46	3/23/2016	3.76	16.65
1/27/2016	4.93	21.83	2/25/2016	6.89	30.51	3/24/2016	2.47	10.94
1/28/2016	5.36	23.74	2/29/2016	7.83	34.68	3/28/2016	3.79	16.78
						3/29/2016	5.28	23.38
						3/30/2016	5.34	23.65
						3/31/2016	4.47	19.80

Table 2-7. Nitrate Process Samples, 2016

Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)
April Average	**5.59**	**24.76**	**May Average**	**4.96**	**21.95**	**June Average**	**9.22**	**40.83**
4/4/2016	0.12	0.54	5/2/2016	1.70	7.53	6/1/2016	5.14	22.76
4/5/2016	5.31	23.52	5/3/2016	0.57	2.51	6/2/2016	5.87	26.00
4/6/2016	7.20	31.89	5/4/2016	1.04	4.61	6/6/2016	13.70	60.67
4/7/2016	9.18	40.65	5/5/2016	1.08	4.78	6/7/2016	12.50	55.36
4/11/2016	8.88	39.33	5/9/2016	5.34	23.65	6/8/2016	11.20	49.60
4/12/2016	7.46	33.04	5/10/2016	1.46	6.47	6/9/2016	12.60	55.80
4/13/2016	6.24	27.63	5/11/2016	1.19	5.27	6/13/2016	9.75	43.18
4/14/2016	7.73	34.23	5/12/2016	1.98	8.77	6/14/2016	9.15	40.52
4/18/2016	7.20	31.89	5/16/2016	8.52	37.73	6/15/2016	7.60	33.66
4/19/2016	11.10	49.16	5/17/2016	12.20	54.03	6/16/2016	7.37	32.64
4/20/2016	2.61	11.56	5/18/2016	8.15	36.09	6/20/2016	11.00	48.71
4/21/2016	5.22	23.12	5/19/2016	5.88	26.04	6/21/2016	14.40	63.77
4/25/2016	2.83	12.53	5/23/2016	9.61	42.56	6/22/2016	9.77	43.27
4/26/2016	4.29	19.00	5/24/2016	4.34	19.22	6/23/2016	8.55	37.86
4/27/2016	2.41	10.67	5/25/2016	3.25	14.39	6/27/2016	7.91	35.03
4/28/2016	1.66	7.35	5/26/2016	6.45	28.56	6/28/2016	6.90	30.56
			5/31/2016	11.50	50.93	6/29/2016	6.67	29.54
						6/30/2016	5.89	26.08

Table 2-7. Nitrate Process Samples, 2016

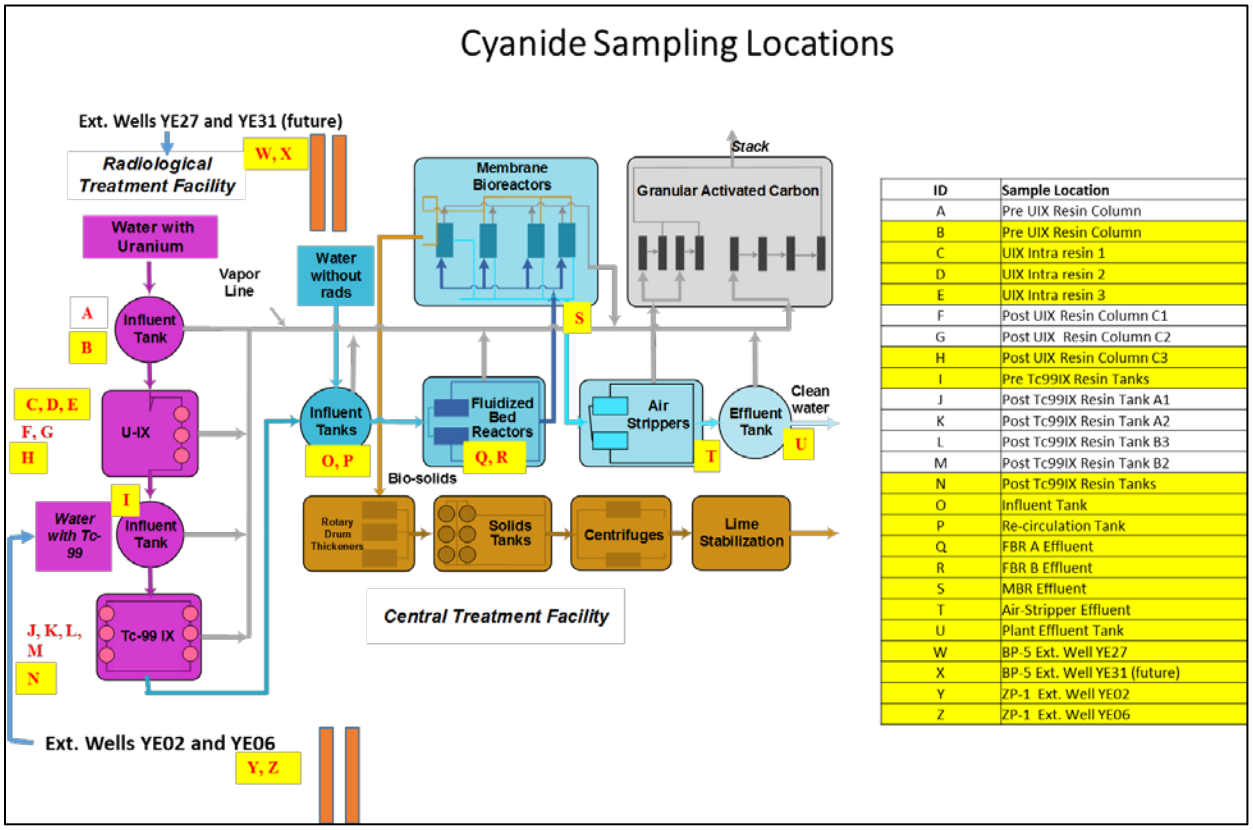
Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)
July Average	**8.31**	**36.79**	**August Average**	**6.85**	**30.34**	**September Average**	**6.39**	**28.31**
7/5/2016	7.65	33.88	8/1/2016	7.58	33.57	9/1/2016	7.07	31.31
7/6/2016	9.99	44.24	8/3/2016	--	--	9/6/2016	8.41	37.24
7/7/2016	6.64	29.41	8/4/2016	6.78	30.03	9/7/2016	7.36	32.59
7/11/2016	8.26	36.58	8/8/2016	4.17	18.47	9/8/2016	7.65	33.88
7/12/2016	7.45	32.99	8/9/2016	4.66	20.64	9/12/2016	4.85	21.48
7/13/2016	7.29	32.28	8/10/2016	7.07	31.31	9/13/2016	3.02	13.37
7/14/2016	8.05	35.65	8/11/2016	13.20	58.46	9/14/2016	3.80	16.83
7/18/2016	12.40	54.91	8/12/2016	9.80	43.40	9/15/2016	4.42	19.57
7/19/2016	10.30	45.61	8/15/2016	7.55	33.44	9/19/2016	5.36	23.74
7/20/2016	8.35	36.98	8/16/2016	5.90	26.13	9/20/2016	4.99	22.10
7/21/2016	6.25	27.68	8/17/2016	6.79	30.07	9/21/2016	8.99	39.81
7/25/2016	8.60	38.09	8/18/2016	2.94	13.02	9/22/2016	6.23	27.59
7/26/2016	6.76	29.94	8/22/2016	6.57	29.10	9/26/2016	7.17	31.75
7/27/2016	8.26	36.58	8/23/2016	6.55	29.01	9/27/2016	6.83	30.25
7/28/2016	8.37	37.07	8/24/2016	5.83	25.82	9/28/2016	7.54	33.39
			8/25/2016	4.30	19.04	9/29/2016	8.58	38.00
			8/29/2016	8.72	38.62			
			8/30/2016	7.05	31.22			
			8/31/2016	7.87	34.85			

Table 2-7. Nitrate Process Samples, 2016

Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)	Date/Time Collected	Plant Effluent Nitrate (mg/L as N)	Plant Effluent Nitrate (mg/L as Nitrate)
October Average	**6.21**	**27.49**	**November Average**	**7.00**	**31.01**	**December Average**	**7.91**	**35.03**
10/3/2016	7.07	31.31	11/1/2016	7.59	33.61	12/1/2016	9.00	39.86
10/4/2016	11.50	50.93	11/2/2016	7.10	31.44	12/5/2016	8.29	36.71
10/5/2016	9.78	43.31	11/3/2016	8.48	37.55	12/6/2016	6.85	30.34
10/6/2016	7.10	31.44	11/7/2016	5.37	23.78	12/7/2016	7.07	31.31
10/10/2016	3.63	16.08	11/8/2016	5.69	25.20	12/8/2016	6.72	29.76
10/11/2016	12.30	54.47	11/9/2016	6.56	29.05	12/12/2016	7.98	35.34
10/17/2016	4.65	20.59	11/10/2016	6.21	27.50	12/13/2016	7.42	32.86
10/18/2016	4.14	18.33	11/14/2016	5.71	25.29	12/14/2016	7.82	34.63
10/19/2016	1.10	4.87	11/15/2016	6.49	28.74	12/15/2016	9.68	42.87
10/20/2016	2.51	11.12	11/16/2016	6.30	27.90	12/19/2016	7.63	33.79
10/24/2016	5.20	23.03	11/17/2016	6.62	29.32	12/20/2016	7.10	31.44
10/25/2016	5.94	26.31	11/21/2016	5.98	26.48	12/21/2016	7.54	33.39
10/26/2016	5.27	23.34	11/22/2016	7.11	31.49	12/27/2016	7.60	33.66
10/27/2016	5.81	25.73	11/28/2016	7.96	35.25	12/28/2016	7.65	33.88
10/31/2016	7.12	31.53	11/29/2016	9.70	42.96	12/29/2016	10.30	45.61
			11/30/2016	9.15	40.52			

With the addition of extracted groundwater from the 200-BP-5 OU in 2015, cyanide was included as a constituent for process monitoring at various points throughout the 200 West P&T treatment process (Figure 2-9). Cyanide is a co-contaminant in the extracted groundwater from the B Complex area in the 200-BP-5 groundwater OU. This water is combined with contaminated water from certain areas in 200 West and is treated through the radiological treatment buildings (Figure 2-9). Process and effluent samples were analyzed for total cyanide in 2015 and 2016. Concentrations of cyanide in the 200 West P&T effluent were all below the 200 µg/L maximum contaminant level (MCL; Table 2-8).

Three monthly effluent samples had cyanide measurements exceeding the 4.8 µg/L Washington State WAC 173-340, "Model Toxics Control Act—Cleanup" (MTCA) cleanup value for free cyanide. The analytical methods used in 2015 and 2016 for the 200 West P&T effluent were to measure total cyanide concentrations. Because the methods run were for total cyanide, it could not be determined if the free cyanide MTCA cleanup value was exceeded. Beginning in 2017, process samples are analyzed for both total and free cyanide at the locations highlighted in yellow in Figure 2-9. Additional analytical analyses for these locations are being evaluated for filtered and nonfiltered water samples.



ID	Sample Location
A	Pre UIX Resin Column
B	Pre UIX Resin Column
C	UIX Intra resin 1
D	UIX Intra resin 2
E	UIX Intra resin 3
F	Post UIX Resin Column C1
G	Post UIX Resin Column C2
H	Post UIX Resin Column C3
I	Pre Tc99IX Resin Tanks
J	Post Tc99IX Resin Tank A1
K	Post Tc99IX Resin Tank A2
L	Post Tc99IX Resin Tank B3
M	Post Tc99IX Resin Tank B2
N	Post Tc99IX Resin Tanks
O	Influent Tank
P	Re-circulation Tank
Q	FBR A Effluent
R	FBR B Effluent
S	MBR Effluent
T	Air-Stripper Effluent
U	Plant Effluent Tank
W	BP-5 Ext. Well YE27
X	BP-5 Ext. Well YE31 (future)
Y	ZP-1 Ext. Well YE02
Z	ZP-1 Ext. Well YE06

Figure 2-9. Measurement Locations for Total and Free Cyanide throughout the 200 West P&T

Table 2-8. Cyanide Concentrations in the 200 West P&T Effluent in 2015 and 2016

Sample Collection Date	Total Cyanide (µg/L)
11/11/2015	3.4 (B)
12/08/2015	10 (U)
01/12/2016	3 (U)
02/23/2016	5.95 (BC)
03/15/2016	3.6 (U)
04/13/2016	3.6 (U)
05/10/2016	3 (BC)
05/20/2016	1.88 (B)
05/27/2016	1.67 (U)
06/27/2016	5.1 (B)
07/20/2016	12
08/22/2016	3.6 (U)
09/14/2016	4.2 (B)
10/31/2016	3.24 (B)
11/30/2016	10.5 (C)
12/29/2016	2.59 (B)

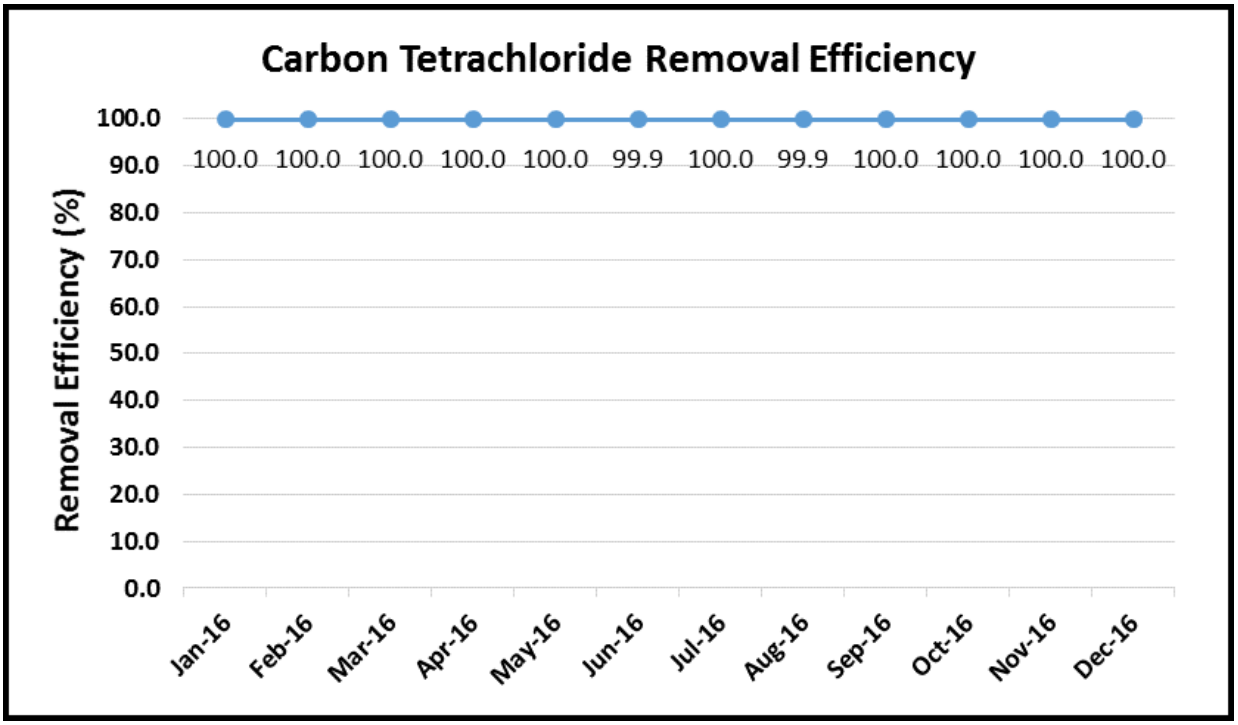
B = Detected at a value less than the contract required detection limit (RDL) ≥ the instrument detection limit (IDL)/method detection limit (MDL)

C = Detected in both the sample and the associated QC blank; sample concentration ≤5X blank concentration

U = Not detected above method detection limit

2.2.5 Treatment Plant Mass Removed

The treatment system performance is evaluated in terms of the contaminant mass removed by the 200 West P&T, treatment facility processes, and operational efficiencies on an annual basis. As shown in Table 2-1, a total of 3.0 billion L (0.8 billion gal) of groundwater was processed through the treatment system in 2016. Table 2-1 provides the total mass of COCs removed in 2016 by the 200 West P&T. Figures 2-10 through 2-13 illustrate the removal efficiency calculated by influent and effluent concentrations at the process facility. The fluctuation in removal efficiency for hexavalent chromium, total chromium, and nitrate (Figures 2-11 and 2-12) reflect process adjustments associated with optimizing the biological treatment process to minimize biofouling (as discussed in Section 2.2.1) and maintain the effluent below cleanup levels. The decline in technetium-99 removal efficiency (Figure 2-12) is due to increasing saturation of the first columns in the IX treatment trains. The IX resin will be changed out when the columns are fully loaded.



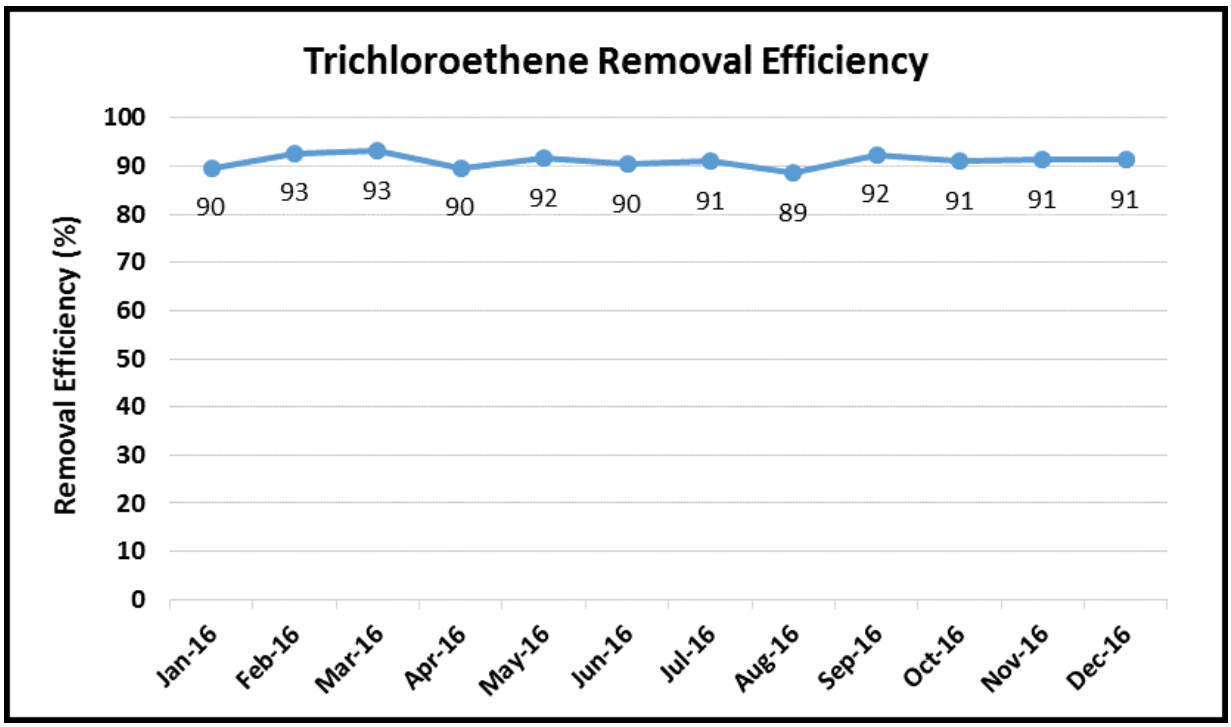
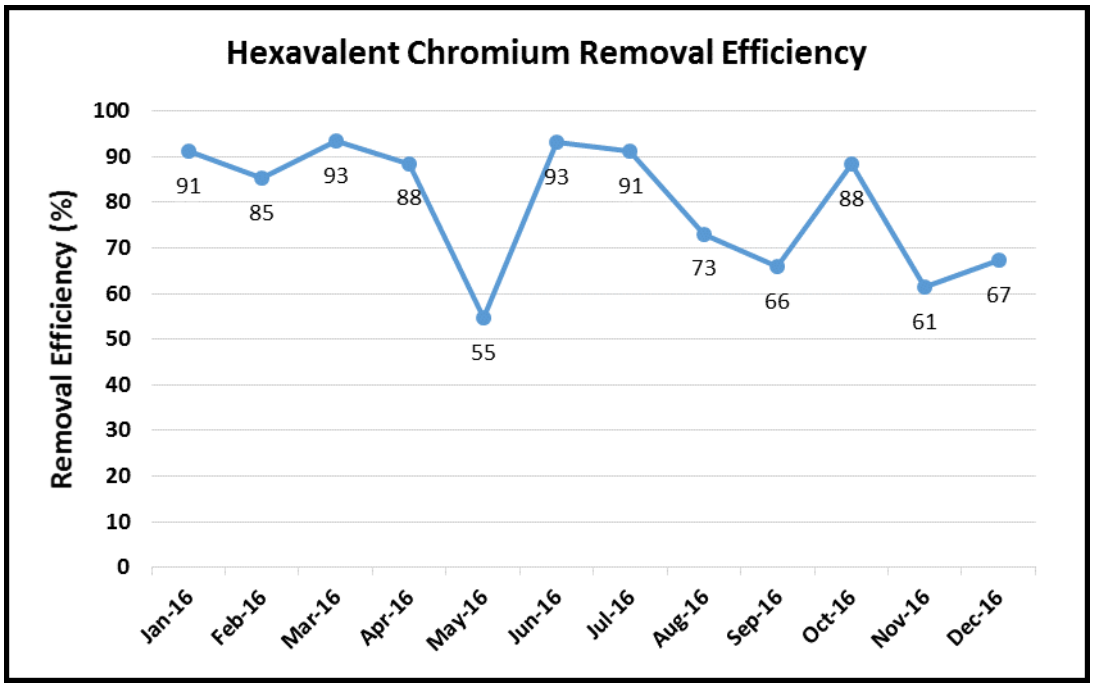


Figure 2-10. COC Removal Efficiency for Carbon Tetrachloride and Trichloroethene



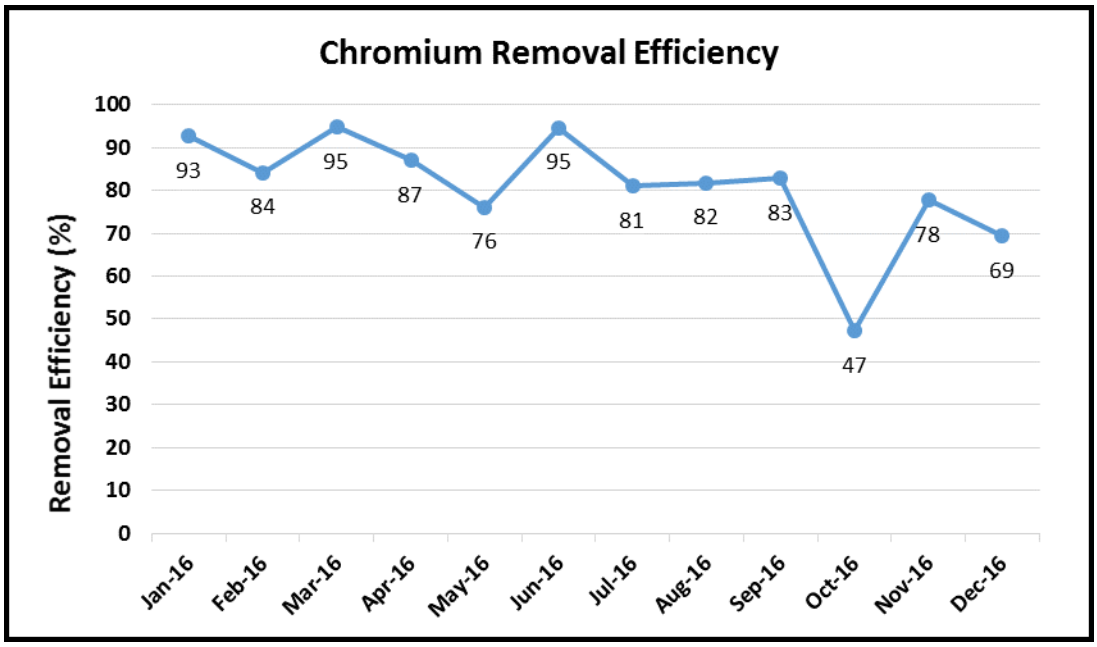
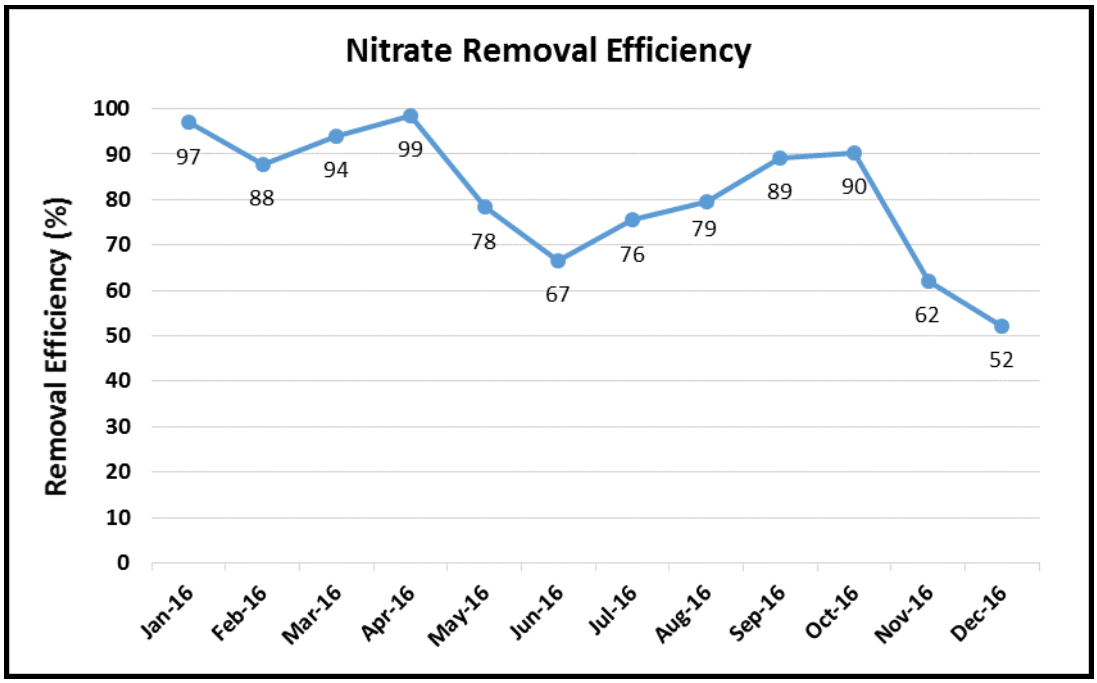


Figure 2-11. COC Removal Efficiency for Hexavalent Chromium and Total Chromium



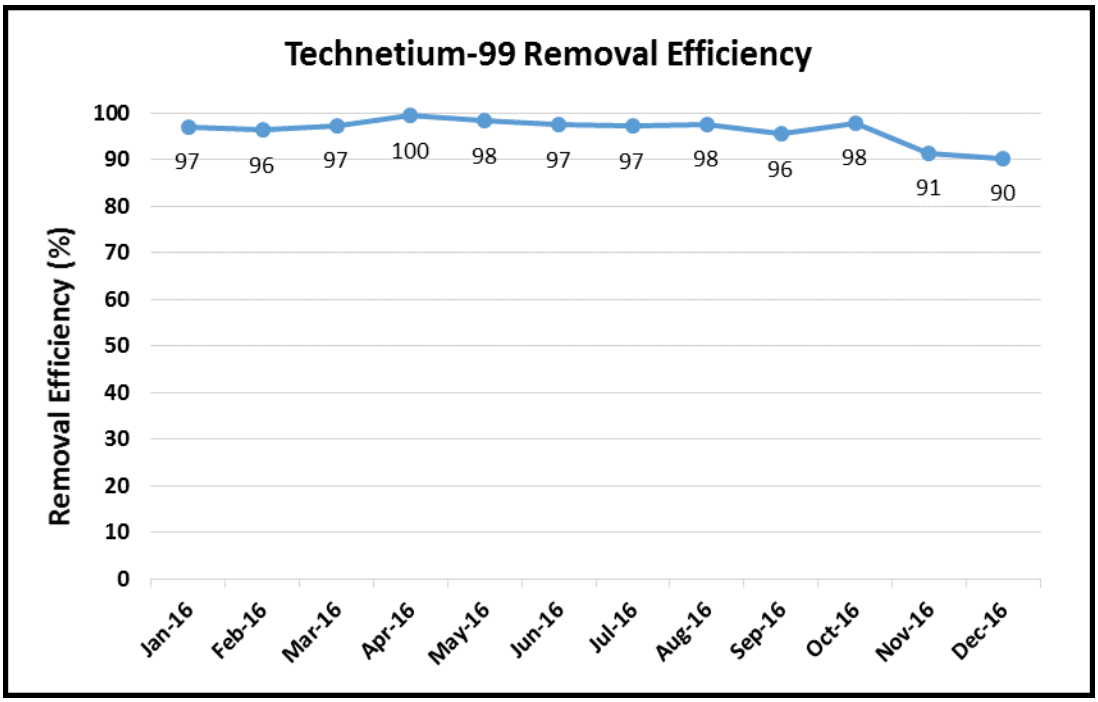


Figure 2-12. COC Removal Efficiency for Nitrate (as Nitrate) and Technetium-99

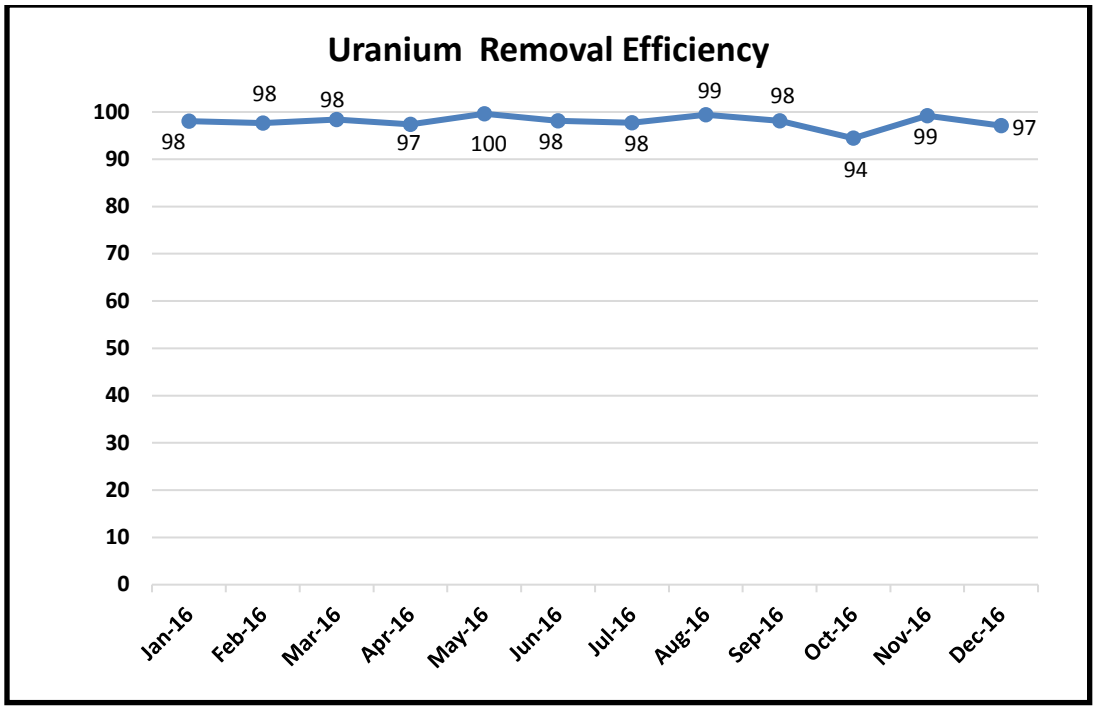


Figure 2-13. COC Removal Efficiency for Uranium

Figure 2-14 illustrates the cumulative mass removed by the system from July 2012, at which time the operation of 200 West P&T began, through December 2016.

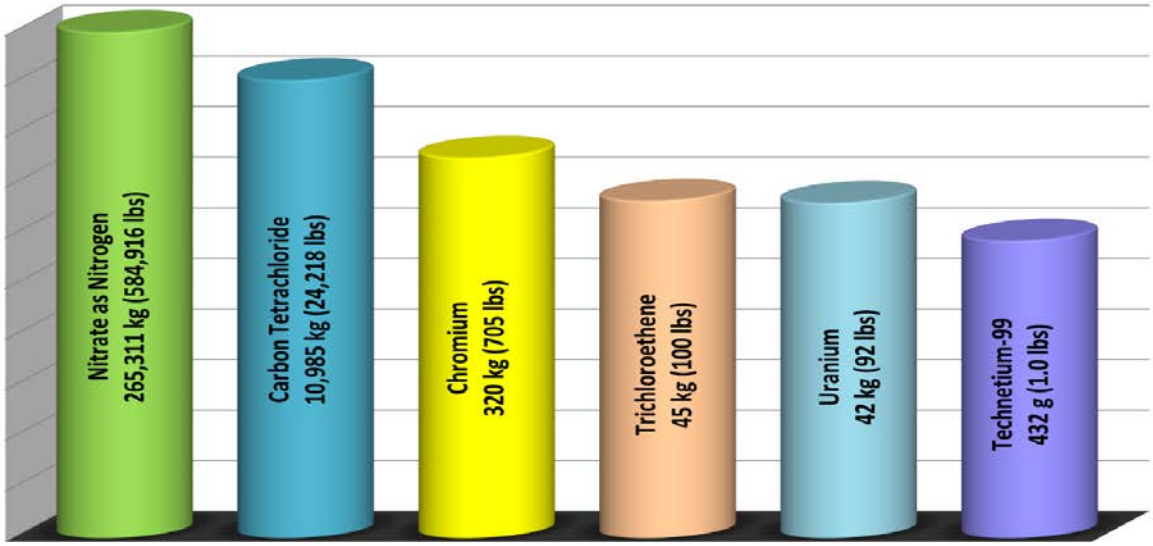


Figure 2-14. Cumulative Contaminant Mass Removed by the 200 West P&T, 2012 through 2016

2.3 Radiological Dose and Drinking Water Standard Analysis of 200 West Pump and Treat Effluent

Effluent water from the 200 West P&T was evaluated for compliance with the requirements for radiological protection of human health and the environment. This evaluation included calculation of the total effective dose (TED) produced by radioisotopes present in the effluent water following treatment of extracted groundwater to remove identified contaminants. The resultant dose was compared to the target dose limit of 100 mrem/yr to the public established in DOE O 458.1. The cumulative TED is based on use of the derived concentration standards (DCSs) defined in DOE-STD-1196-2011, *Derived Concentration Technical Standard*. Additional guidance for screening of radiological dose related to discharge of liquid effluents at DOE facilities is provided in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, which provides recommended criteria for radiological effluent monitoring based on the DCS to ensure effective effluent monitoring that identifies problematic effluent conditions before they exceed target metrics.

This evaluation further compares the radioisotopes present in effluent water to the following radiological drinking water standards (DWSs): the 4 mrem/yr MCL dose for beta/photon emitters and the 30 µg/L uranium mass concentration MCL. The recommended criteria described in DOE-HDBK-1216-2015 are summarized in Table 2-9.

Table 2-9. Recommended Criteria for Liquid Radiological Effluent Monitoring (from Table 3-1 of DOE-HDBK-1216-2015)

Criterion Number	Derived Concentration Standards Sum-of-Fractions		Potential Annual Dose from Exposure to a Likely Receptor (mrem)	Minimum Criteria for Liquid Radiological Effluent Monitoring
1	≥1	and	--	1. Apply best available technology to reduce effluent releases (except H-3). 2. Use continuous monitoring/sampling, but where effluent streams are low flow and potential public dose is very low (<<1 mrem in a year), alternative sampling approaches may be appropriate.
2	≥0.01 to 1	and	>1	1. Continuously monitor or sample. 2. Identify radionuclides contributing ≥10% of the dose. 3. Determine accuracy of results (± accuracy and percent confidence level).
3	≥0.001 to 0.01	and	<1	1. Monitor using a graded approach to select the appropriate method and duration. 2. Identify radionuclides contributing ≥10% or more of the dose. 3. Assess annually the facility inventory and potential for radiological effluent release.
4	<0.001	and	--	1. No monitoring required. 2. Evaluate annually the potential for liquid radiological effluent release.

Source: DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

2.3.1 Evaluation of Effluent Water Total Effective Dose for 200 West Pump and Treat for Calendar Year 2016

Effluent monitoring at the 200 West P&T was performed using sampling and analysis of the stream exiting the plant prior to pumping effluent to the injection well field. Sampling and analysis was performed on a monthly basis for target radionuclides identified as contaminants of interest for the groundwater remedial actions supported by the treatment system. The target radionuclides for the 200 West P&T were tritium, iodine-129, strontium-90, carbon-14, uranium, cesium-137, cobalt-60, and technetium-99. The results of monthly sampling and analysis are summarized in Table 2-10.

Individual radioisotope activity concentrations were subsequently converted to estimated effective dose using the DCS values in Table 2-11.The individual radioisotope dose contributions for each effluent sampling event at the 200 West P&T and the cumulative TED estimates for CY 2016 are shown in Table 2-12. The TED was calculated using two approaches. The first was a conservative approach incorporating the minimum detectable activity (MDA) for nondetect measurements as a value; the second included no value for nondetect measurements. The resultant TED and DCS fractions were then compared to the criteria presented in Table 2-9.

The cumulative TED and DCS fraction values shown in Table 2-12 indicated that results of all sampling events during CY 2016 met monitoring criterion 3, with the exception of samples analyzed on May 20 and May 27, 2016. TED and DCS fraction values for those two sampling events met monitoring criterion 2. Further evaluation of the uncertainty in calculated cumulative TED and DSC fraction values based on the use of MDA values for nondetect measurements of iodine-129, strontium-90, carbon-14, cesium-137, and cobalt-60 indicates that the use of MDA values contributes substantially to the calculated TED. Further evaluation of the results indicates that strontium-90, carbon-14, cesium-137, and cobalt-60 were not detected in any sampling event. Iodine-129 was detected in only one sampling event (i.e., February 23, 2016). Based on this examination of reported radioisotopic measurements, the estimated TED and DSC fraction based on reported values for detected radioisotopes only is found to provide the most representative analysis of the effluent monitoring data. The effluent monitoring data are, therefore, determined to meet criterion 2 as presented in Table 2-9, and continued monthly sampling and analysis with annual review is the recommended approach for effluent monitoring at the 200 West P&T.

2.3.2 Comparison of 200 West Pump and Treat Effluent Water Radiological Constituents to Drinking Water Standards for Beta/Photon Emitters and Uranium for Calendar Year 2016

Radiological constituents listed in Table 2-13 were also evaluated against the drinking water dose MCL of 4 mrem/yr for beta/photon emitters. The total uranium concentration was also evaluated against the 30 µg/L uranium MCL. The cumulative beta/photon dose MCL is based on a sum-of-fractions calculation (similar to the *Atomic Energy Act of 1954* DCS TED), using the derived concentration values published by the U.S. Environmental Protection Agency (EPA). The results of this comparison are presented in Table 2-13. The beta/photon MCL dose analysis was done in two ways: using the reported MDA as a value for measurements reported as nondetects, and not including any value for nondetected isotopes. The first approach is used as a conservative screen to assess potential dose contributions. In this instance, 9 of the 12 sampling events for 200 West P&T effluent would exceed the MCL sum of fractions, driven primarily by the MDA values for iodine-129. Review of the laboratory performance indicates that the iodine-129 measurements met the required target MDA of less than 1 pCi/L. Further evaluation of the count uncertainty indicates that the high end of the count error band for the reported nondetects would be greater than the reported MDA for 6 of the sampling events, but would only exceed the 1 pCi/L derived concentration in 3 of the 12 sampling events. Based on analysis of the relative uncertainty in iodine-129 measurements, the sum-of-fractions analysis based on use of reported detections only was selected as the most representative approach. In this instance, only one of the sampling events (i.e., January 12, 2016) is

observed to have exceeded the beta/photon emitter dose MCL with a sum of fractions of 1.10 and resultant dose of 4.39 mrem/yr. Using this analysis, it is determined that the 200 West P&T effluent consistently, although not exclusively, met the MCL dose standard for beta/photon emitters. Furthermore, the monthly sampling and analysis frequency appears to be adequate to address potential variability in the effluent stream.

Uranium mass concentration in 200 West P&T effluent (Table 2-10) was consistently less than 2 µg/L in all sample events, confirming that the effluent uranium concentration meets the MCL uranium mass concentration standard of less than 30 µg/L.

2.3.3 Conclusions of Evaluation of Radiological Constituents in 200 West Pump and Treat Effluent Water for Calendar Year 2016

Evaluation of radiological dose and uranium mass concentration of 200 West P&T effluent water during CY 2016 indicates that the effluent met the following standards and criteria:

- The calculated DCS-based TED of the effluent was consistently less than 1 mrem/yr, substantially below the 100 mrem/yr public dose limit.
- The calculated DCS-based sum of fractions and resultant TED of the effluent was consistent with recommended monitoring criteria indicating that monthly sampling and analysis with annual review remains an appropriate frequency.
- The measured uranium mass concentration in effluent was consistently an order-of-magnitude below the 30 µg/L uranium MCL.
- The calculated MCL-based beta/photon emitter dose was below the 4 mrem/yr MCL dose for 11 of the 12 sample events. One event exceeded the MCL dose due to a low-level detection of iodine-129.

No changes in the effluent monitoring sampling and analysis frequency or analytical suite are indicated for CY 2017.

Table 2-10. Summary of Effluent Radioisotope Sampling and Analysis Results for CY 2016 at the 200 West P&T

Sample Location	Sample Date	Tritium (pCi/L)	I-129 (pCi/L)[a]	Sr-90 (pCi/L)[a]	C-14 (pCi/L)[a]	U (µg/L)	U-238 [b] (pCi/L)	U-235 [b] (pCi/L)	U-234 [b] (pCi/L)	Cs-137 (pCi/L)[a]	Co-60 (pCi/L)[a]	Tc-99 (pCi/L)[a]
Effluent tank - Y80	01/12/16	2,720	(0.69)	-NM-	-NM-	1	0.333	0.015	0.3750	-NM-	(3.75)	33.9
	02/23/16	3,210	0.855	-NM-	-NM-	1.1	0.366	0.017	0.41300	(3.72)	(4.48)	73.5
	03/15/16	3,560	(0.925)	-NM-	-NM-	0.91	0.303	0.014	0.34100	(3.54)	(4.02)	57.5
	04/13/16	3,170	(0.88)	-NM-	-NM-	1.1	0.366	0.017	0.41300	-NM-	(3.22)	(9.95)
	05/10/16	2,390	(0.795)	-NM-	(17)	0.98	0.326	0.0148	0.368	-NM-	(4.04)	26.4
	05/20/16	5,800	(0.973)	(1.3)	(41.9)	1.62	0.539	0.025	0.608	(2.56)	(3.21)	56.3
	05/27/16	3,625	(0.997)	(1.71)	(31.6)	1.27	0.422	0.019	0.476	(4.37)	(4.62)	63.6
	06/27/16	2,895	(0.691)	-NM-	-NM-	0.77	0.256	0.012	0.289	-NM-	(3.18)	69.6
	07/20/16	2,910	(0.865)	-NM-	-NM-	1	0.333	0.015	0.3750	-NM-	(3.94)	69.6
	08/22/16	3,240	(0.92)	-NM-	-NM-	0.86	0.286	0.013	0.323	-NM-	(3.35)	65.7
	09/14/16	3,790	(0.626)	-NM-	-NM-	0.85	0.283	0.013	0.319	-NM-	(3.62)	92.9
	10/31/16	2,820	(0.771)	-NM-	-NM-	1.52	0.506	0.023	0.570	-NM-	(3.73)	36.5
	11/30/16	2,815	(0.928)	-NM-	-NM-	1	0.333	0.015	0.3750	-NM-	(4.3)	141
	12/29/16	2,390	(0.737)	-NM-	-NM-	0.92	0.306	0.014	0.345	-NM-	(4.21)	134

a. Values in parentheses were reported as not detected. Value presented is the reported MDA concentration for samples reported as analyzed but not detected.

b. Uranium isotope (i.e., U-234, U-235, and U-238) activity concentrations are derived from uranium mass concentration values assuming the mass distribution and specific activity of isotopes in natural uranium.

-NM- = constituent not measured in this sampling and analysis event

Table 2-11. Derived Concentration Standards for Radioisotopes Evaluated in 200 West P&T Effluent

DCS	Tritium	I-129	Sr-90	C-14	U [a]	U-238	U-235	U-234	Cs-137	Co-60	Tc-99
DCS (µCi/mL) [b]	1.90E-03	3.30E-07	3.30E-07	6.20E-05		7.50E-07	7.20E-07	6.80E-07	3.00E-06	7.20E-06	4.40E-05
DCS (pCi/L) [c]	1.90E+06	3.30E+02	3.30E+02	6.20E+04		7.50E+02	7.20E+02	6.80E+02	3.00E+03	7.20E+03	4.40E+04

a. Uranium in mass concentration is not assigned a DCS value.

b. DCS from Table 5 of DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

c. DCS converted to pCi/L for direct comparison to measurement results.

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Table 2-12. Calculated Individual Radioisotope Dose Contributions and TED for 200 West P&T Effluent in CY 2016

Sample Location	Sample Date	Individual Isotope Effective Dose Contribution										TED Cumulative mR/yr	DCS Fraction Cumulative Fraction	TED Detects Only mR/yr	DCS Fraction Detects Only Fraction
		Tritium (mR/yr)	I-129 (mR/yr) [a]	Sr-90 (mR/yr) [a]	C-14 (mR/yr) [a]	U-238 [b] (mR/yr)	U-235 [b] (mR/yr)	U-234 [b] (mR/yr)	Cs-137 (mR/yr) [b]	Co-60 (mR/yr) [a]	Tc-99 (mR/yr) [a]				
Effluent tank	01/12/16	1.4E-01	(2.6E-01)			4.4E-02	2.1E-03	5.5E-02		(5.2E-02)	7.7E-02	0.634 [c]	0.0063 [c]	0.322 [c]	0.0032 [c]
	02/23/16	1.7E-01	2.6E-01			4.9E-02	2.3E-03	6.1E-02	(1.2E-01)	(6.2E-02)	1.7E-01	0.895 [c]	0.0089 [c]	0.709 [c]	0.0071 [c]
	03/15/16	1.9E-01	(2.8E-01)			4.0E-02	1.9E-03	5.0E-02	(1.2E-01)	(5.6E-02)	1.3E-01	0.871 [c]	0.0087 [c]	0.417 [c]	0.0042 [c]
	04/13/16	1.7E-01	(2.7E-01)			4.9E-02	2.3E-03	6.1E-02		(4.5E-02)	(2.3E-02)	0.617 [c]	0.0062 [c]	0.283 [c]	0.0028 [c]
	05/10/16	1.3E-01	(2.4E-01)		(2.7E-02)	4.3E-02	2.1E-03	5.4E-02		(5.6E-02)	6.0E-02	0.610 [c]	0.0061 [c]	0.285 [c]	0.0029 [c]
	05/20/16	3.1E-01	(2.9E-01)	(3.9E-01)	(6.8E-02)	7.2E-02	3.4E-03	8.9E-02	(8.5E-02)	(4.5E-02)	1.3E-01	1.484 [d]	0.0148 [d]	0.598 [c]	0.0060 [c]
	05/27/16	2.0E-01	(3.0E-01)	(5.2E-01)	(5.1E-02)	5.6E-02	2.7E-03	7.0E-02	(1.5E-01)	(6.4E-02)	1.4E-01	1.553 [d]	0.0155 [d]	0.472 [c]	0.0047 [c]
	06/27/16	1.5E-01	(2.1E-01)			3.4E-02	1.6E-03	4.3E-02		(4.4E-02)	1.6E-01	0.644 [c]	0.0064 [c]	0.390 [c]	0.0039 [c]
	07/20/16	1.6E-01	(2.6E-01)			4.4E-02	2.1E-03	5.5E-02		(5.5E-02)	1.6E-01	0.734 [c]	0.0073 [c]	0.417 [c]	0.0042 [c]
	08/22/16	1.7E-01	(2.8E-01)			3.8E-02	1.8E-03	4.8E-02		(4.7E-02)	1.5E-01	0.734 [c]	0.0073 [c]	0.409 [c]	0.0041 [c]
	09/14/16	2.7E-01	(1.9E-01)			3.8E-02	1.8E-03	4.7E-02		(5.0E-02)	2.1E-01	0.808 [c]	0.0081 [c]	0.568 [c]	0.0057 [c]
	10/31/16	1.5E-01	(2.3E-01)			6.7E-02	3.2E-03	8.4E-02		(5.2E-02)	8.3E-02	0.672 [c]	0.0067 [c]	0.386 [c]	0.0039 [c]
	11/30/16	1.5E-01	(2.8E-01)			4.4E-02	2.1E-03	5.5E-02		(6.0E-02)	3.2E-01	0.913 [c]	0.0091 [c]	0.572 [c]	0.0057 [c]
	12/29/16	1.3E-01	(2.2E-01)			4.1E-02	1.9E-03	5.1E-02		(5.8E-02)	3.0E-01	0.808 [c]	0.0081 [c]	0.526 [c]	0.0053 [c]

a. Values in parentheses were reported as not detected. Value presented is dose contribution based on MDA concentration for samples reported as analyzed but not detected.

b. Uranium isotope activity concentrations were derived from total uranium mass concentration for use in calculation of dose contribution.

c. Cumulative TED and DCS fraction values meet criterion 3 in Table 2-9.

d. Shaded cells = cumulative TED and DCS fraction values meet criterion 2 in Table 2-9.

Table 2-13. Summary of Drinking Water Beta/Photon Emitter MCL Comparison for 200 West P&T Effluent for CY 2016

Sample Location	Sample Date	Contributing Radioisotopes							Sum of Fractions [a]	Drinking Water Beta/Photon Dose (mrem/yr) [a]	Sum of Fractions Detects Only [b]	Drinking Water Beta/Photon Dose from Detects Only (mrem/yr) [b]
		Tritium	I-129	Sr-90	C-14	Cs-137	Co-60	Tc-99				
		Derived Concentrations (pCi/L)										
		20000	1	8	2000	200	100	900				
		Beta/Photon MCL Fraction										
Effluent tank	01/12/16	0.14	(0.86) [c]	--	--		(0.04) [c]	0.04	1.07	4.27	0.17	0.70
	02/23/16	0.16	0.86	--	--	(0.02) [c]	(0.04) [c]	0.08	1.16	4.65	1.10	4.39
	03/15/16	0.18	(0.93) [c]	--	--	(0.02) [c]	(0.04) [c]	0.06	1.23	4.93	0.25	0.99
	04/13/16	0.16	(0.88) [c]	--	--	--	(0.03) [c]	(0.01) [c]	1.09	4.35	0.16	0.65
	05/10/16	0.12	(0.80) [c]	--	(0.01)[c]	--	(0.04) [c]	0.03	0.99	3.97	0.15	0.60
	05/20/16	0.29	(0.97) [c]	(0.16)[c]	(0.02)[c]	(0.01)[c]	(0.03) [c]	0.06	1.55	6.22	0.35	1.41
	05/27/16	0.19	(1.00) [c]	(0.21)[c]	(0.02)[c]	(0.02)[c]	(0.05) [c]	0.07	1.55	6.22	0.26	1.04
	06/27/16	0.15	(0.69) [c]	--	--	--	(0.03) [c]	0.08	0.95	3.78	0.22	0.89
	07/20/16	0.15	(0.87) [c]	--	--	--	(0.04) [c]	0.08	1.13	4.52	0.23	0.91
	08/22/16	0.16	(0.92) [c]	--	--	--	(0.03) [c]	0.07	1.19	4.76	0.24	0.95
	09/14/16	0.26	(0.63) [c]	--	--	--	(0.04) [c]	0.10	1.02	4.09	0.36	1.44
	10/31/16	0.14	(0.77) [c]	--	--	--	(0.04) [c]	0.04	0.99	3.96	0.18	0.73
	11/30/16	0.14	(0.93) [c]	--	--	--	(0.04) [c]	0.16	1.27	5.08	0.30	1.20
	12/29/16	0.12	(0.74) [c]	--	--	--	(0.04) [c]	0.15	1.05	4.20	0.27	1.08

a. MCL sum of fractions and calculated drinking water dose using reported MDA values as measured values. Shaded cells indicated sampling event exceeds the MCL of 4 mrem/yr.

b. MCL sum of fractions and calculated drinking water dose using only measured values reported as detected. Shaded cells indicated sampling event exceeds the MCL of 4 mrem/yr.

c. Values in parentheses were reported as not detected in this sampling event; the indicated value is the reported value of the MDA for this isotope.

2.4 200 West Pump and Treat Facility System Costs

This section presents the actual cost breakdown for 200 West P&T operations for 2016, and the cost per unit mass is calculated for specific COCs. This encompasses the 200-ZP-1 OU remedy costs since the cost estimates in the 200-ZP-1 ROD (EPA et al., 2008) integrate the 200 West P&T as part of the overall remedy. Costs are separated into specific activities that can be categorized as either operational or capital expenses. The primary categories of expenditures are described as follows:

- **Design**: Includes initial design activities to support P&T system construction, permitting, aquifer response modeling, peer reviews, QA, and all other design documentation. It is not applicable in the current discussion of costs but is included to provide historical perspective. It also includes the design of system upgrades and modifications.
- **Treatment system capital construction**: Includes fees paid to the construction subcontractor for capital equipment, initial facility construction, construction of new wells, redevelopment of existing wells, and modifications to the P&T system. Includes all construction subcontractor and CHPRC labor required for oversight and support of initial well installation.
- **Project support**: Includes activities related to project coordination and technical consultation as required during the course of the facility design, construction, acceptance testing, and operation. Adjustments are made to reported numbers to represent the actual amount that project support accrued from program/project management and project controls.
- **Operations and Maintenance (O&M)**: Includes facility supplies, labor, and craft supervision costs associated with operating and maintaining the facility. It also includes costs associated with routine field screening and engineering support as required during the course of the P&T operations and periodic maintenance.
- **Performance monitoring**: Includes system and groundwater sampling and sample analysis as required in accordance with the P&T remedial design report (DOE/RL-2010-13), 200-ZP-1 remedial design/remedial action work plan (RD/RAWP) (DOE/RL-2008-78, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*), and PMP (DOE/RL-2009-115). It also includes preparation of the annual performance evaluation report and subsequent reports, as required by the RD/RAWPs and PMPs.
- **Waste management**: Includes the estimated cost for management of GAC, IX resins, bioreactor sludge, and other miscellaneous waste related to the 200 West P&T in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Waste designation sampling and analysis is included.
- **Well installation**: Includes costs for the installation of new *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring, extraction, and injection wells within the 200-ZP-1 OU.

Table 2-14 provides costs for the 200 West P&T. Most of the costs from 2009 through 2012 (89.4%) are associated with design and construction of the 200 West P&T. Although the 200 West P&T did not start operating until July 2012, O&M costs reflected in Table 2-14 for 2009 through 2011 include treatability testing associated with designing the 200 West P&T system, sampling and analyzing groundwater from new well installations for the system, and preparing the O&M plan and PMP.

Table 2-14. Cost Breakdown for the 200 West P&T

Description	Actual Costs ($K)							
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Design	7,981.7	4,563.6	—	—	—	—	70.1	9.7
Treatment system capital	4,631.5	55,476	141,525.1	27,725	—	—	2,514.5	1,100.7
Project support	9.5	113.6	48.4	310.3	451.7	354	136.4	59.4
Operations and maintenance	5.7	2,303.2	289.1	12,693	18,460.9	19,046.4	18,833.5	18,510.7
Performance monitoring	—	96.5	54.6	349	$531.9	243.5	331.4	645.1
Waste management	—	—	—	40.5	$485.5	226.7	260.6	51.2
Regeneration subcontract	—	—	—	—	$22.4	204.5	145.2	330.5
Well installation	4,240	4,959	3,136.2	1,394.3	1,687.6	7,924.6	3,302.8	1,086.2
Totals	**16,868.4**	**67,511.9**	**145,053.4**	**42,512.1**	**21,640**	**27,999.8**	**25,594.5**	**21,793.5**

— = not applicable

Total cost for the 200 West P&T during 2016 was $21.8 million (sum of the categories shown in Table 2-14), a 14.9% reduction from the total cost in 2015 of $25.6 million associated mainly with decrease in well installation and construction. The percentage of 2016 costs, in decreasing order, includes O&M (84.9%), treatment system capital (5.1%), well installation (5.0%), performance monitoring (3.0%), regeneration (1.5%), project support (0.3%), waste management (0.2%), and design (<0.1%).

The cost per unit volume treated and mass recovered by the 200 West P&T was calculated based on capital construction cost for the 200 West P&T system (amortized over the 25-year design life), plus annual O&M costs, divided by the annual volume of groundwater treated or mass removed. The amortized cost of the 200 West P&T is $10.9 million, and the 2016 O&M cost was $18.5 million. In 2016, the 200 West P&T treated 3,038.7 million L (802.7 million gal), removing a combined total of 332,857 kg of contaminants (primarily carbon tetrachloride [1,721 kg], nitrate as NO_3 [330,877 kg], chromium [69.7 kg], and TCE [8.6 kg]). The cost for groundwater treatment in 2016 was $0.01/L, and the cost for contaminant mass removal in 2015 was $98.2/kg.

3 200-UP-1 Operable Unit Remedial Actions

This chapter discusses groundwater remedial actions within the 200-UP-1 OU. At the end of 2016, three active remedies were operating: WMA S-SX groundwater extraction system, U Plant area P&T system, and iodine-129 plume hydraulic containment system. The WMA S-SX groundwater extraction system, which began operating in July 2012, is focused on removing technetium-99 from the aquifer east of the tank farms; however, nitrate, chromium, and carbon tetrachloride are also removed. The U Plant area P&T system came online in September 2015 and removes uranium, technetium-99, and nitrate from the groundwater downgradient from the 216-U-1 and 216-U-2 Cribs. The iodine-129 plume hydraulic containment system began operating during October 2015 with the objective of preventing eastward migration of the iodine-129 plume while treatment technologies for the plume are investigated.

This chapter describes results of contaminant monitoring, hydraulic analyses, flow rates and volumes for the extraction and injection wells, and amount of contaminant removed from the aquifer. This information is used to assess progress toward achieving the RAOs and to assess remedy performance so operational improvements can be made, if needed. This chapter also addresses progress in characterizing the chromium plume southeast of the 200 West Area as well as MNA.

The 200-UP-1 OU addresses groundwater contaminant plumes beneath the southern third of the 200 West Area and adjacent portions of the surrounding 600 Area. The primary sources of groundwater contamination in the OU were waste sites associated with operation of the Reduction-Oxidation (REDOX) Plant for plutonium/uranium separation and operation of the U Plant for uranium recovery. Technetium-99, uranium, tritium, iodine-129, nitrate, chromium, and carbon tetrachloride form groundwater plumes in the area. These contaminants originated from operations in this area, except for carbon tetrachloride, which is associated with the Plutonium Finishing Plant (PFP) overlying the 200-ZP-1 OU.

Groundwater remediation is addressed by the 200-UP-1 ROD for interim action (EPA et al., 2012). The selected remedy consists of the following components:

- Groundwater extraction and treatment with MNA for all COCs except iodine-129 and tritium
- MNA for the entire tritium plume and parts of the nitrate and carbon tetrachloride plumes not captured by the groundwater extraction remedies
- Hydraulic containment for iodine-129 while treatment technologies are investigated
- Remedy performance monitoring
- Institutional controls (ICs)

The RAOs are as follows:

- **RAO #1**: Return the 200-UP-1 OU groundwater to beneficial use as a potential drinking water source.
- **RAO #2**: Prevent human exposure to contaminated 200-UP-1 OU groundwater that exceeds acceptable risk levels for drinking water.

Table 3-1 lists cleanup levels specified in the 200-UP-1 ROD (EPA et al., 2012). The RD/RAWP (DOE/RL-2013-07, *200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*) describes implementation of the ROD (EPA et al., 2012). Remedy performance monitoring is described in a PMP (DOE/RL-2015-14, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*). Sampling requirements to meet the PMP were implemented starting in January 2016. The PMP describes groundwater monitoring data collection activities associated with implementation of the 200-UP-1 OU remedial action. This chapter describes groundwater sampling performed in 2016.

Table 3-1. Cleanup Levels for 200-UP-1 OU COCs

Contaminants of Concern	Units	90th Percentile Groundwater Concentrations	Federal DWS [a]	WAC 173-340 Method B Cleanup Levels		Cleanup Level
				Noncarcinogens at Hazard Quotient = 1	Carcinogens at 1×10^{-6} Risk Level	
Iodine-129	pCi/L	3.5	1	N/A	N/A	1 [b]
Technetium-99	pCi/L	4,150	900	N/A	N/A	900
Tritium	pCi/L	51,150	20,000	N/A	N/A	20,000
Uranium	µg/L	206	30	N/A	N/A	30
Nitrate [c] (as NO_3)	mg/L	133	45 [c]	113.6	N/A	45
Nitrate [c] (as N)	mg/L	30.1	10 [c]	25.6	N/A	10
Total chromium	µg/L	99	100	24,000	N/A	100
Hexavalent chromium	µg/L	52	N/A [d]	48	N/A	48
Carbon tetrachloride	µg/L	189	5	5.6	0.34 [e]	3.4 [f]

References: EPA et al., 2012, *Record of Decision for Interim Remedial Action Hanford 200 Area Superfund Site 200-UP-1 Operable Unit* (Table 14).

WAC 173-340-705, "Model Toxics Control Act—Cleanup," "Use of Method B."

a. Federal DWS is from 40 CFR 141, "National Primary Drinking Water Regulations," with iodine-129 and technetium-99 values from EPA 816-F-00-002, *Implementation Guidance for Radionuclides.*

b. Currently identified groundwater treatment technology is insufficient to reach the 1 pCi/L DWS.

c. Nitrate (NO_3) may be expressed as the ion NO_3 (NO_3- NO_3) or as nitrogen (NO_3-N). The federal DWS for nitrate is published as 10 mg/L expressed as N, which is equivalent to 45 mg/L expressed as NO_3- (rounded to the nearest 5 µg/L). The Washington State cleanup level is 25.6 mg/L, as nitrogen.

d. There is no federal DWS for hexavalent chromium.

e. This value is based on estimated risk from an individual contaminant at the 1×10^{-6} risk level.

f. This cleanup level is a risk-based calculation for carbon tetrachloride. This value represents a cumulative 1×10^{-5} risk in accordance with WAC 173-340-720(7)(a), "Groundwater Cleanup Standards."

EPA = U.S. Environmental Protection Agency

N/A = not applicable

Section 3.1 provides an overview of the hydraulic monitoring network for the 200-UP-1 OU and methods of data analysis to determine capture. Sections 3.2, 3.3, and 3.4 address operation of the WMA S-SX groundwater extraction system, U Plant area P&T system, and iodine-129 plume hydraulic containment system, respectively. Each section addresses operation of the remedy, hydraulic analysis results, and contaminant monitoring. Section 3.5 describes plans to progress in characterizing the chromium plume southeast of the 200 West Area, and Section 3.6 addresses MNA. Section 3.7 references where sampling QA/QC information is reported, and cost information is provided in Section 3.8. Section 3.9 includes the conclusions.

3.1 200-UP-1 Hydraulic Monitoring Overview

This section provides an overview of the hydraulic monitoring program for 200-UP-1 and presents the 2016 water table map for the OU. Hydraulic monitoring is needed to assess remedy performance, identify future directions of plume migration, support groundwater flow model calibration, and determine future usability of the monitoring wells. Section 3.2 of the PMP (DOE/RL-2015-14) describes the hydraulic monitoring program in detail.

Water level measurements are collected at different frequencies and from different networks in the OU. Synoptic sets of measurements are collected annually in March from a network of wells across the OU (Figure 3-1). These measurements are used to prepare the regional water table map for the OU. Water level measurements are collected more frequently from smaller well networks near the active remedies (Figures 3-2 and 3-3), and the data are analyzed for capture analyses. During 2016, monthly water level measurements were collected for the WMA S-SX groundwater extraction system, U Plant area P&T system, and iodine-129 plume hydraulic containment system. In addition to the manual measurements, automated water levels are collected hourly from a network of 13 wells near the WMA S-SX and U Plant area remedies (Figure 3-2).

Water level data are analyzed by preparing potentiometric surface maps which indicate the configuration of the water table. Potentiometric surface maps for the active remedies are prepared using multi-event universal kriging (MEUK; Tonkin et al., 2013, *A Hybrid Analytic Element Universal Kriging Interpolation Technique Built in Open Source R Environment*) and incorporating analytical expressions representing the effects of groundwater extraction and injection as detailed in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*. When using MEUK to interpolate the water level data, an event is composed of an essentially contemporaneous set of water level measurements obtained within a sufficiently brief time period (i.e., a synoptic set of measurements). For the 200-UP-1 OU, water level measurements collected throughout the year are grouped into monthly events and then analyzed collectively to produce a potentiometric surface map for each month. Thus, MEUK leverages information from multiple time periods and well networks to make use of all available water level information when interpolating a potentiometric surface for a particular month. Once a set of potentiometric surface maps is prepared for an active remedy, a single map is chosen for particle tracking analysis to determine the local capture zone. More details of the MEUK methodology can be found in Section 3.2.1 of the PMP (DOE/RL-2015-14).

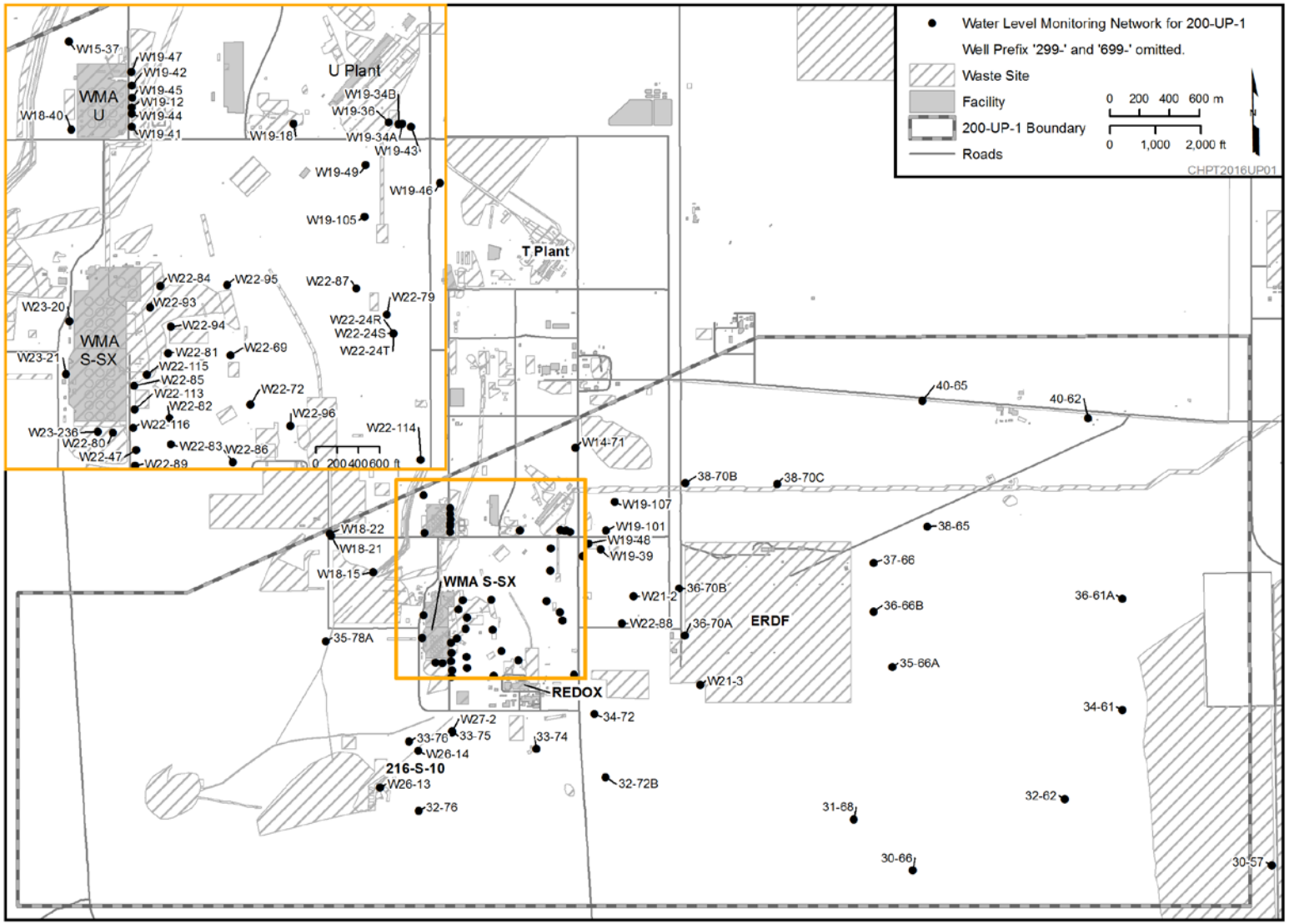


Figure 3-1. Regional Water Level Monitoring Network for the 200-UP-1 OU

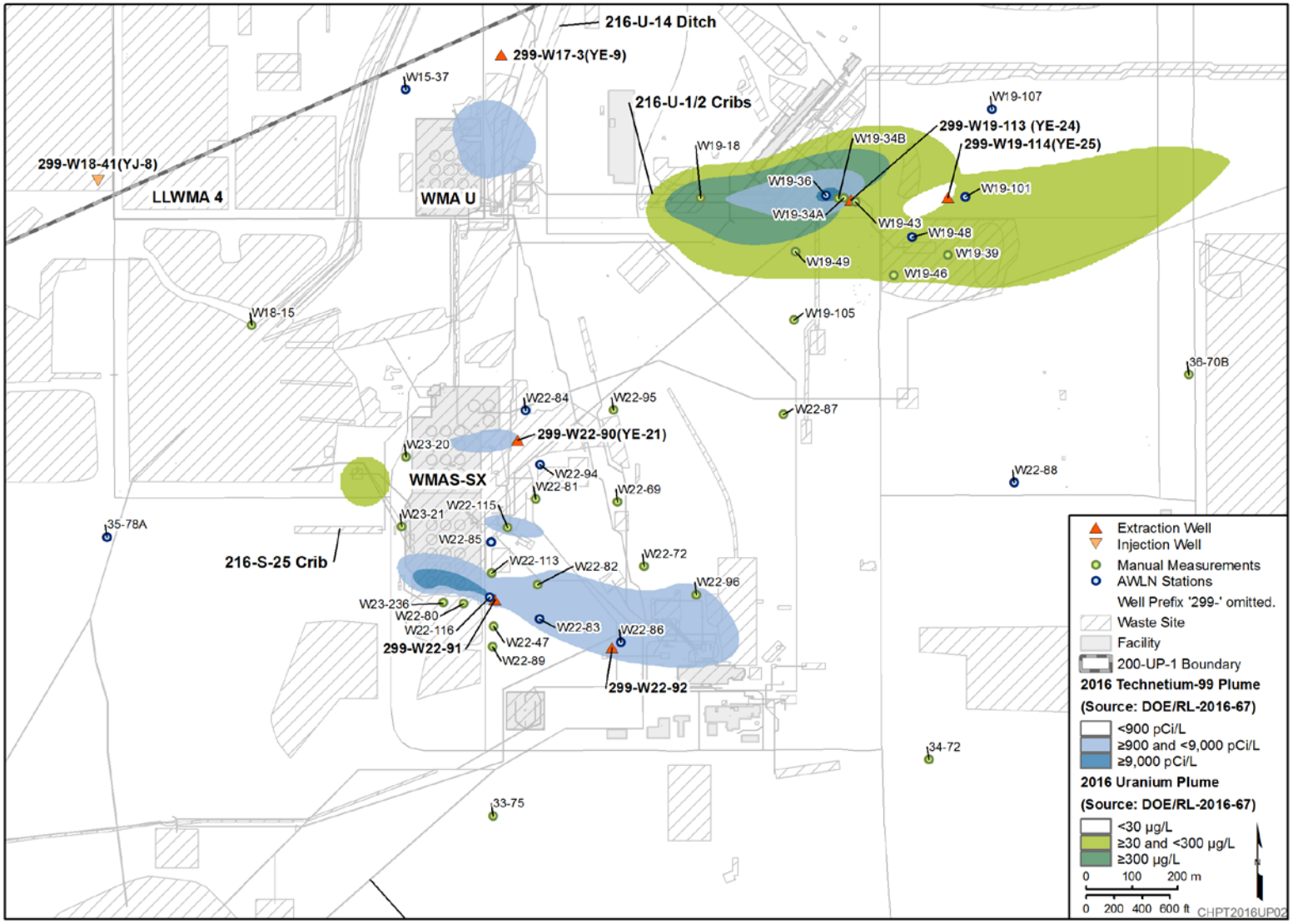


Figure 3-2. Water Level Monitoring Network for the WMA S-SX and U Plant Area Active Remedies

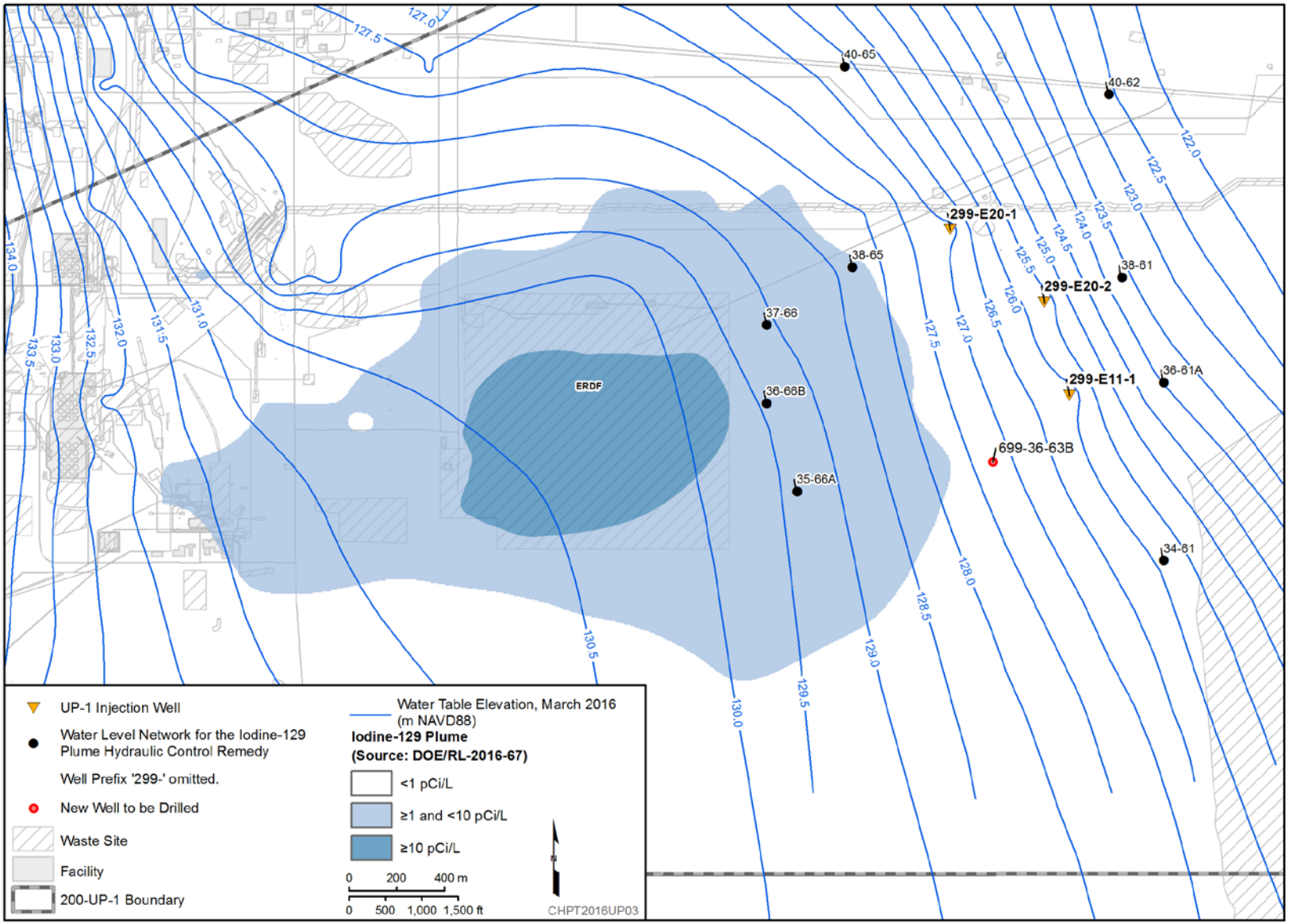


Figure 3-3. Water Level Monitoring Network for the Iodine-129 Plume Hydraulic Containment Remedy

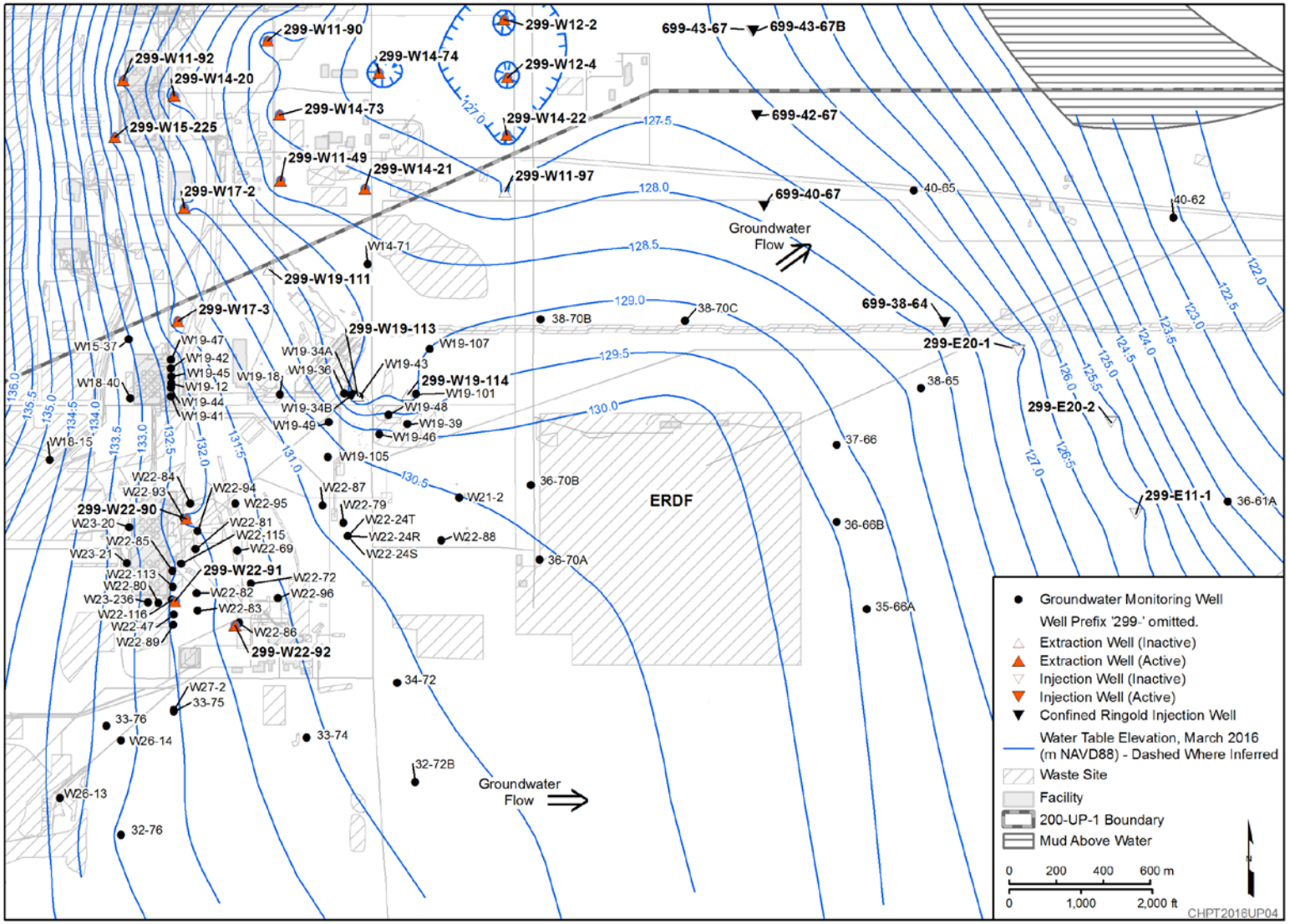
The 200-UP-1 regional water table map for March 2016 is presented in Figure 3-4. This map provides the context for more detailed hydraulic analyses of the active remedies presented in the following sections. The regional map was prepared by a combination of kriging near the WMA S-SX groundwater extraction system and manual contouring elsewhere. The kriging methodology used is documented in SGW-42305 and consists of universal kriging modified by the incorporation of equations that describe the effect of other stressors and features on water levels, including groundwater extraction and injection. Because the resulting potentiometric surface map includes information on stressors and other features, it is typically more hydraulically plausible than maps constructed using other methods.

The regional water table map indicates that groundwater flow is generally toward the east within the southern 200 West Area and toward the east-northeast in the eastern portion of the OU (Figure 3-4). The magnitude of the hydraulic gradient becomes higher toward the east. This is caused at least partly by a decrease in the aquifer saturated thickness and the corresponding decrease in transmissivity. The Ringold lower mud (RLM) unit, which forms the base of the unconfined aquifer, increases in elevation toward the east resulting in a thinning aquifer. The hydraulic conductivity of the aquifer sediments may also decrease toward the east, which would contribute to the larger hydraulic gradient. In the north-central portion of the OU, including within the U Plant area extending to ERDF (Figure 3-4), the groundwater flow direction has been substantially altered by the 200 West P&T in the 200-ZP-1 OU and the U Plant P&T. Groundwater extraction by these systems has substantially drawn down the water table causing the groundwater flow direction in this area to be north-northeast toward the 200-ZP-1 extraction wells.

3.2 S-SX Tank Farms Remedial System

The S-SX Tank Farms consist of underground storage tanks: 12 single-shell tanks (SSTs) in the S Tank Farm, and 15 SSTs in the SX Tank Farm. The tanks hold high-level waste from plutonium/uranium separation activities conducted at the REDOX Plant. One tank in the S Tank Farm and eight tanks in the SX Tank Farm are known or assumed to have experienced a leak/release (HNF-EP-0182, *Waste Tank Summary Report for Month Ending December 31, 2015*). To minimize future leaks/releases, most of the drainable liquid in the tanks has been removed and transferred to double-shell tanks (i.e., the tanks have been interim stabilized; HNF-EP-0182).

Releases from the tanks have resulted in groundwater contamination beneath and downgradient of the S-SX Tank Farms (PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*; DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*). Major contaminant plumes associated with the tank farms include technetium-99, chromium, and nitrate. Iodine-129 and selenium-79 have been found in groundwater and are attributed to releases from the tanks, but these constituents occur at low concentrations. Carbon tetrachloride in the groundwater originates from PFP operations overlying the 200-ZP-1 OU. Some PFP waste streams were disposed to the 216-U-10 Pond (U Pond), which is a possible source of carbon tetrachloride upgradient from the S-SX Tank Farms. Tritium and some of the nitrate also originate from an upgradient source (i.e., 216-S-25 Crib).



Note: Figure depicts the status of injection and extraction wells as of March 2015.

Figure 3-4. Water Table Map for the 200-UP-1 OU, March 2016

The selected remedy in the 200-UP-1 ROD to address increasing technetium-99 concentrations in groundwater beneath and downgradient of the S-SX Tank Farms, includes groundwater extraction consisting of three extraction wells with a total average extraction rate of 303 L/min (80 gpm) for 15 years. The groundwater extraction system, which was constructed during 2011, consists of three extraction wells: one well downgradient from the S Tank Farm (299-W22-90 [YE-21]), and two wells downgradient from the SX Tank Farm (299-W22-91 [YE-22] and 299-W22-92 [YE-23]; Figure 3-5). The system was designed to extract technetium-99 from the groundwater and reduce the size of the plumes. The system also extracts the collocated chromium plume and portions of the nitrate and carbon tetrachloride plumes. The extraction wells were designed to intercept the observed depth of the technetium-99 plume. Wells 299-W22-90 and 299-W22-92 are screened to 15.1 m (50 ft) below the baseline water table, while 299-W22-91 is screened to 18.7 m (61.5 ft) below the baseline water table.

The extracted groundwater is pumped to the 200 West P&T using aboveground pipelines and a transfer building (DOE/RL-2013-07). The 200 West P&T consists of two main processes:

- Radiological pretreatment process using IX resins (primarily to remove technetium-99, but some iodine-129 is also removed)
- Central treatment process that uses anoxic and aerobic biodegradation for nitrate, metals, and organic contaminants; membrane filtration to remove particulate matter; and air stripping to remove VOCs

Groundwater pumped by the WMA S-SX extraction wells is combined with groundwater pumped by the 200-ZP-1, 200-BP-5, and 200-DV-1 OU's extraction wells that require radionuclide treatment, and the combined water is passed through the IX resin. The effluent from this process is then combined with groundwater from the remaining extraction wells (not requiring radionuclide treatment) and passed through the central treatment process. The treated water is then returned to the aquifer using injection wells, most of which are located within the 200-ZP-1 OU. The treatment system is further described in Chapter 2.

3.2.1 Remedial System Operation

The WMA S-SX groundwater extraction system operated more than 90% of the time during 2016 with at least one of the three extraction wells pumping. Extraction wells 299-W22-90, 299-W22-91, and 299-W22-92 were in operation pumping water for 73%, 98%, and 99% of the time in 2016, respectively. The extraction wells were periodically shut down for system maintenance, but almost all of these instances lasted less than 2 days. Water was pumped from the aquifer every day except two (March 9-10) during 2016.

Data used to monitor remedial system operation consist of flow rates from the extraction wells, sample results from the extraction wells, and influent/effluent sample results from the treatment system.

3.2.1.1 Extraction Well Flow Rates

Weekly average flow rates per extraction well are shown in Figure 3-6. Average flow rates during the year were 91 L/min (24 gpm) for 299-W22-90, 129 L/min (34 gpm) for 299-W22-91, and 125 L/min (33 gpm) for 299-W22-92. This yielded a combined average flow rate of 345 L/min (91 gpm), 114% of the design nominal pumping rate of 303 L/min (80 gpm). This was a decrease of 3 L/min (1 gpm) over the average flow rates for 2015. The total volume of water extracted from the aquifer during 2016 was 167 million L (44.1 million gal), and the total since startup in July 2012 was 677 million L (179 million gal).

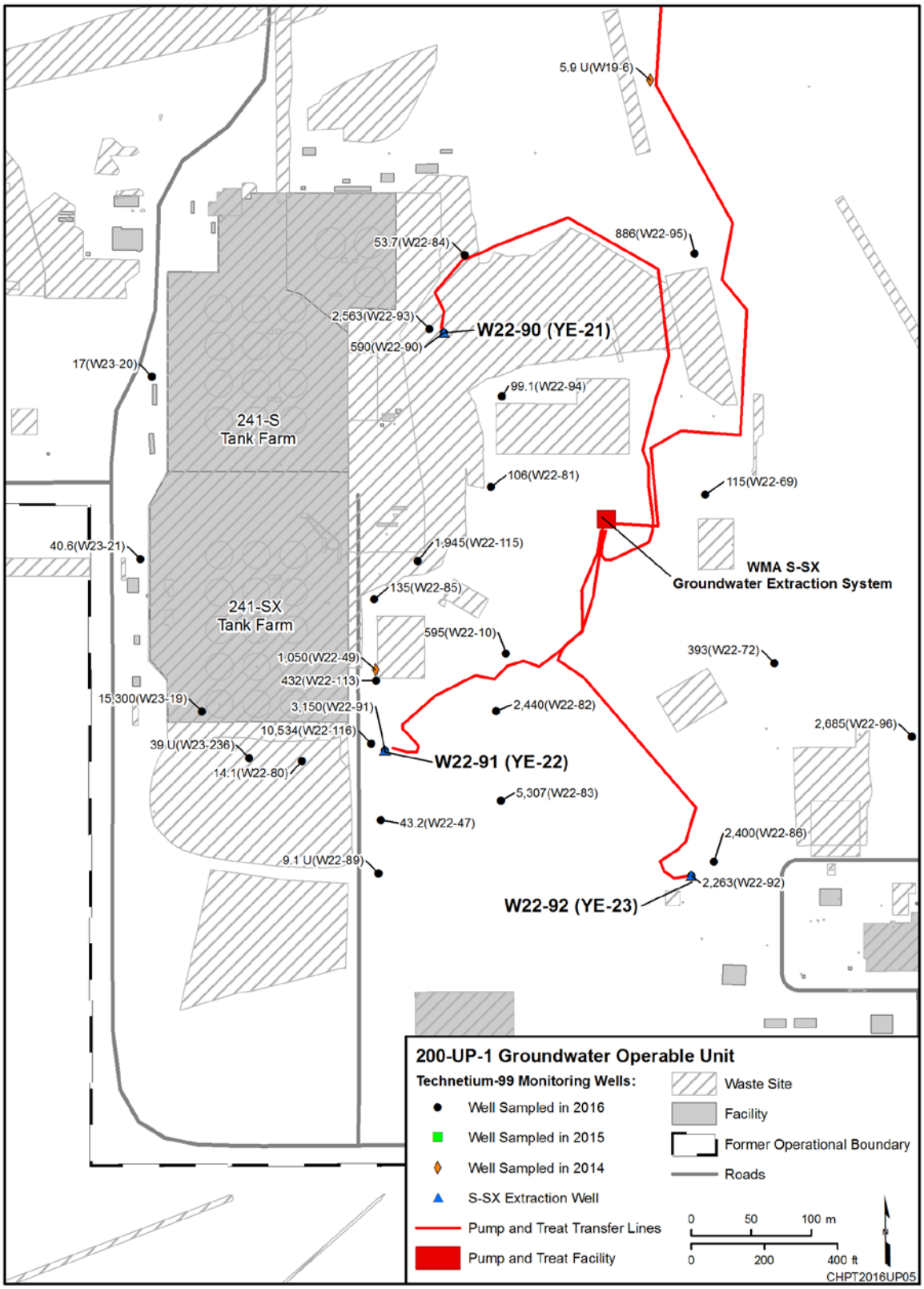


Figure 3-5. WMA S-SX Groundwater Extraction System and Monitoring Wells

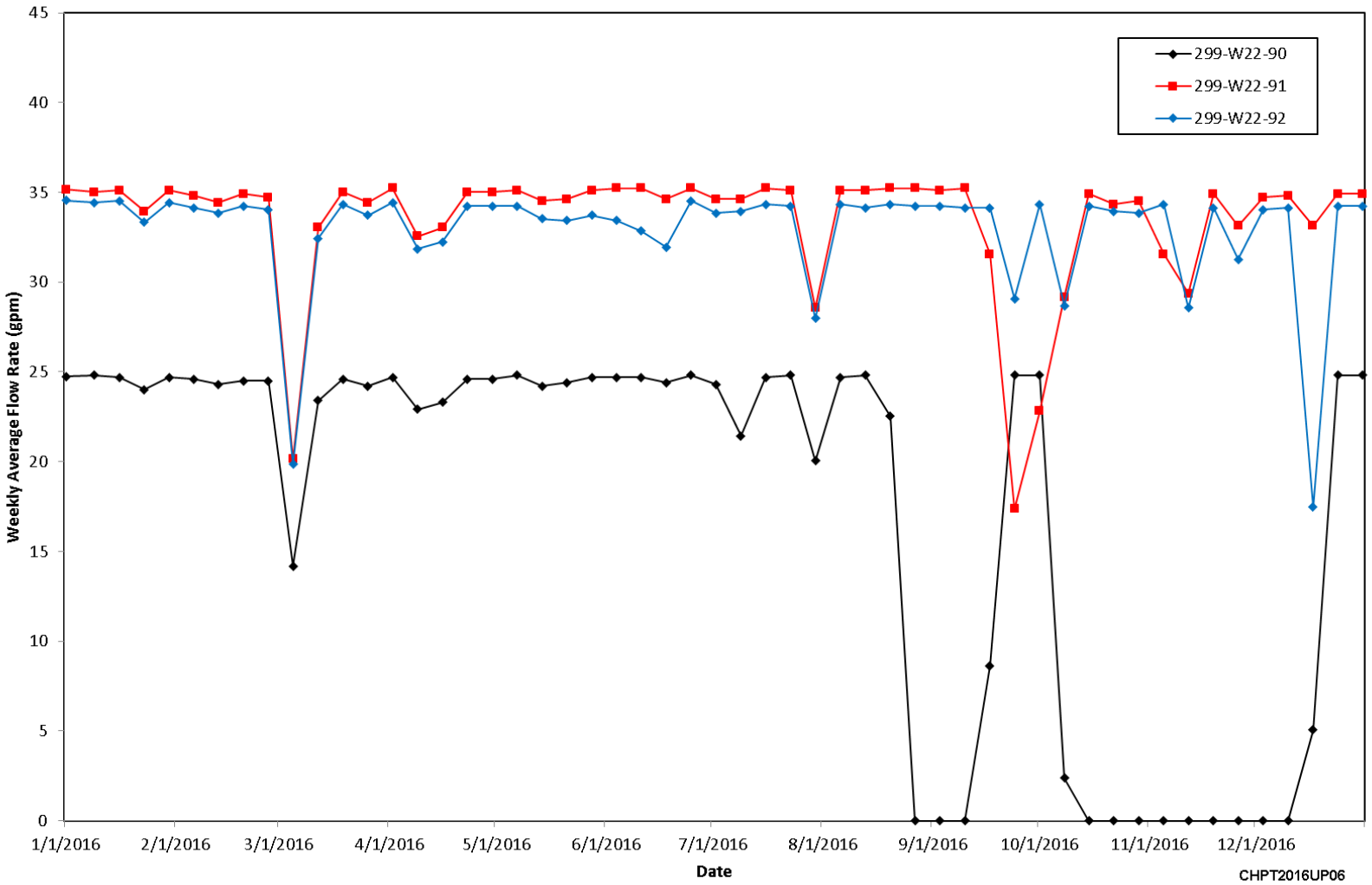


Figure 3-6. Weekly Average Pumping Rates during 2016 for the WMA S-SX Groundwater Extraction System

3.2.1.2 Extraction Well Mass Removal

The WMA S-SX extraction wells are sampled quarterly, and the results for 2016 are provided in Table 3-2. The sample results and the extraction well flow rates were used to estimate the total mass (or activity) of the primary constituent (technetium-99), as well as the secondary constituents (chromium, nitrate, and carbon tetrachloride) removed from the aquifer (Table 3-3). Although tritium is present in the groundwater, the amount of tritium removed from the aquifer is not shown in Table 3-3 because the treatment system does not remove tritium from the groundwater. Thus, water injected into the aquifer contains tritium (i.e., no net removal of tritium from the aquifer occurs). The average monthly tritium concentration in the effluent from the treatment facility (Chapter 2, Section 2.2.4, Table 2-6) ranged from 2,390 to 4,248 pCi/L during 2016.[1]

Table 3-2. Extraction Well Sample Results for the WMA S-SX Groundwater Extraction System

Well Name	Constituent	01/13/2016 Result	04/19/2016 Result	08/22/2016 Result	12/07/2016 Result
299-W22-90 (YE-21)	Carbon tetrachloride (µg/L)	83	74	79[a]	NA
	Chromium (µg/L)	35	34	30	NA
	Hexavalent chromium (µg/L)	43	39	33[a]	NA
	Nitrate (mg/L as NO_3)	27.0	25.7	25.7	NA
	Technetium-99 (pCi/L)	663	623	559[b]	NA
299-W22-91 (YE-22)	Carbon tetrachloride (µg/L)	67	62	61	63
	Chromium (µg/L)	33	33	30	25
	Hexavalent chromium (µg/L)	39	37	33	31
	Nitrate (mg/L as NO_3)	31.9	31.0	29.2	29.7
	Technetium-99 (pCi/L)	3,210	3,510	2,850	3,030
299-W22-92 (YE-23)	Carbon tetrachloride (µg/L)	68	65	72	68
	Chromium (µg/L)	32	30	28	22
	Hexavalent chromium (µg/L)	37	33	30	28
	Nitrate (mg/L as NO_3)	31.9	31.0	29.2	29.7
	Technetium-99 (pCi/L)	2,500	2,430	2,030	2,090

a. Maximum of duplicate sample results.

NA = not available

[1] In the 200-UP-1 ROD (EPA et al., 2012), the selected remedy for tritium within the 200-UP-1 OU is MNA. Reduction in tritium concentrations will be achieved by natural radiological decay (half-life of 12.3 years).

Table 3-3. Contaminant Mass (or Activity) Removed from the Aquifer by the WMA S-SX Groundwater Extraction System

Constituent	Mass (Activity) Removed	
	During 2016	Since Startup
Technetium-99, g (Ci)	22.3 (0.378)	150.9 (2.56)
Chromium (total and hexavalent), kg	5.4	41.4
Nitrate (as NO_3), kg	4,910	27,510
Carbon tetrachloride, kg	11.4	50.9

3.2.1.3 Treatment System Mass Removal

As stated, extracted groundwater is conveyed to the 200 West P&T, and it passes through IX resin for radiological treatment. Effluent from the resin is then combined with the influent groundwater from other extraction wells (that do not require radiological treatment) and is passed through the central treatment process. Effluent from the treatment system is then injected into the aquifer using the 200-ZP-1 injection wells. Section 2.1 (Chapter 2) provides a description of the treatment system and its performance during 2016. The technetium-99 removal efficiency for the entire system averaged 96% during 2016 (Chapter 2, Section 2.1, Table 2-1), and average concentrations in effluent from the treatment system met all of the cleanup levels specified in the 200-UP-1 ROD (EPA et al., 2012; Chapter 2, Section 2.2.4, Table 2-6).

3.2.2 Water Level Monitoring

Water level monitoring is performed to evaluate the effect of the WMA S-SX groundwater extraction system on the water table and effectiveness of the system in capturing the contaminant plumes. The following subsections describe the data interpretation for 2016.

3.2.2.1 Water Level Measurements

During 2016, synoptic manual depth-to-water measurements were collected monthly from monitoring wells near the WMA S-SX groundwater extraction system. In accordance with DOE/RL-2015-14, monthly manual measurements will be collected for 1 year, then an evaluation will be made to determine if the measurement frequency can be reduced (e.g., to quarterly). Some wells are equipped with pressure transducers and data loggers for automated water level measurements (Figure 3-2). When reviewing and interpreting water level data, the flow rates recorded at each extraction well are also reviewed to provide an understanding of the probable causes of changes in groundwater levels.

The WMA S-SX groundwater extraction system is located adjacent to (south of) the 200 West P&T within the 200-ZP-1 OU. The large volume of water pumped by the 200-ZP-1 wells causes a large water table response that affects water levels near WMA S-SX. The monitoring well network for the 200-ZP-1 remedy also includes a large number of wells used to obtain manual depth-to-water measurements and wells equipped with transducers for automated water levels. For these reasons, groundwater levels near the WMA S-SX system are interpreted using data from both the WMA S-SX and 200-ZP-1 OU monitoring networks.

3.2.2.2 Hydraulic Capture Analysis

Groundwater levels and pumping rates were interpreted to estimate the hydraulic capture zone of the WMA S-SX groundwater extraction system. Figure 3-7 depicts the estimated time-dependent capture zone developed by groundwater extraction at the WMA S-SX groundwater extraction system during March 2016, together with the mapped technetium-99 plume in groundwater. The capture zone was estimated by mapping the groundwater elevation data for March 2016 using MEUK and tracking particles on the mapped surface for a duration of 12 years (i.e., until 2027, which is 15 years after the start of groundwater extraction [i.e., estimated time required to meet the RAOs]). Particle tracking was performed by releasing particles in a circle, enveloping each extraction well, and tracking them backward. This results in an instantaneous depiction of the extent of capture under March 2016 conditions (i.e., groundwater flow lines depict the approximate area of the aquifer that would be captured by the extraction wells over a 12-year period if the water table configuration during March 2016 represented steady-state conditions). The calculated groundwater flow lines indicate the focus area of hydraulic containment and mass recovery for the WMA S-SX extraction wells under current conditions.

Figure 3-7 indicates that the system will capture most of the technetium-99 plumes that occur between the extraction wells and tank farms at concentrations at or above 900 pCi/L. Concentrations in the portions not being captured (e.g., east of extraction wells) are predicted to decline to below the cleanup level by natural attenuation. This conclusion is based on results of the fate and transport modeling performed for the remedial investigation (RI) and feasibility study (FS). Modeling performed to evaluate the WMA S-SX groundwater extraction system indicated that the mean plume concentration (as determined by the 95% upper confidence limit [UCL_{95}]) would decline to below the cleanup level 15 years after the start of the active remedy (Figure 6-11 in Appendix D of DOE/RL-2009-122, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*).

The remedy for the chromium and nitrate plumes in the WMA S-SX vicinity is natural attenuation. However, portions of these plumes are being captured by the groundwater extraction system because they are co-located with the technetium-99 plumes. Figures 3-8 and 3-9 show the March 2016 capture zones with the chromium and nitrate plumes (the small chromium and nitrate plumes at the 216-S-20 Crib shown in Figures 3-8 and 3-9 originate from that crib and not from the S-SX Tank Farms). The capture zone at 299-W22-90 covers that portion of the chromium plume upgradient from the extraction well at the 48 µg/L concentration level (i.e., the cleanup level). In the SX Tank Farm plume, extraction wells 299-W22-91 and 299-W22-92 are effectively capturing nearly all portions of the chromium plume above 48 µg/L. A similar extent of capture occurs for the nitrate plume, except the portion of the plume from the 216-S-25 Crib that is beneath and downgradient from the northern SX Tank Farm and is not within a capture zone. To reiterate, capture of the chromium and nitrate plumes at WMA S-SX is not a requirement of the groundwater extraction system and this capture analysis is provided for information only.

3.2.3 Contaminant Monitoring

This section summarizes the 2016 results for groundwater sampling near the WMA S-SX groundwater extraction system. A comprehensive discussion of groundwater contamination within the OU is provided in the RI/FS (DOE/RL-2009-122). The vertical distribution of the plumes is shown as cross-sectional maps in the RD/RAWP (DOE/RL-2013-07). Discussions of recent monitoring results for the entire OU are provided in DOE/RL-2016-67.

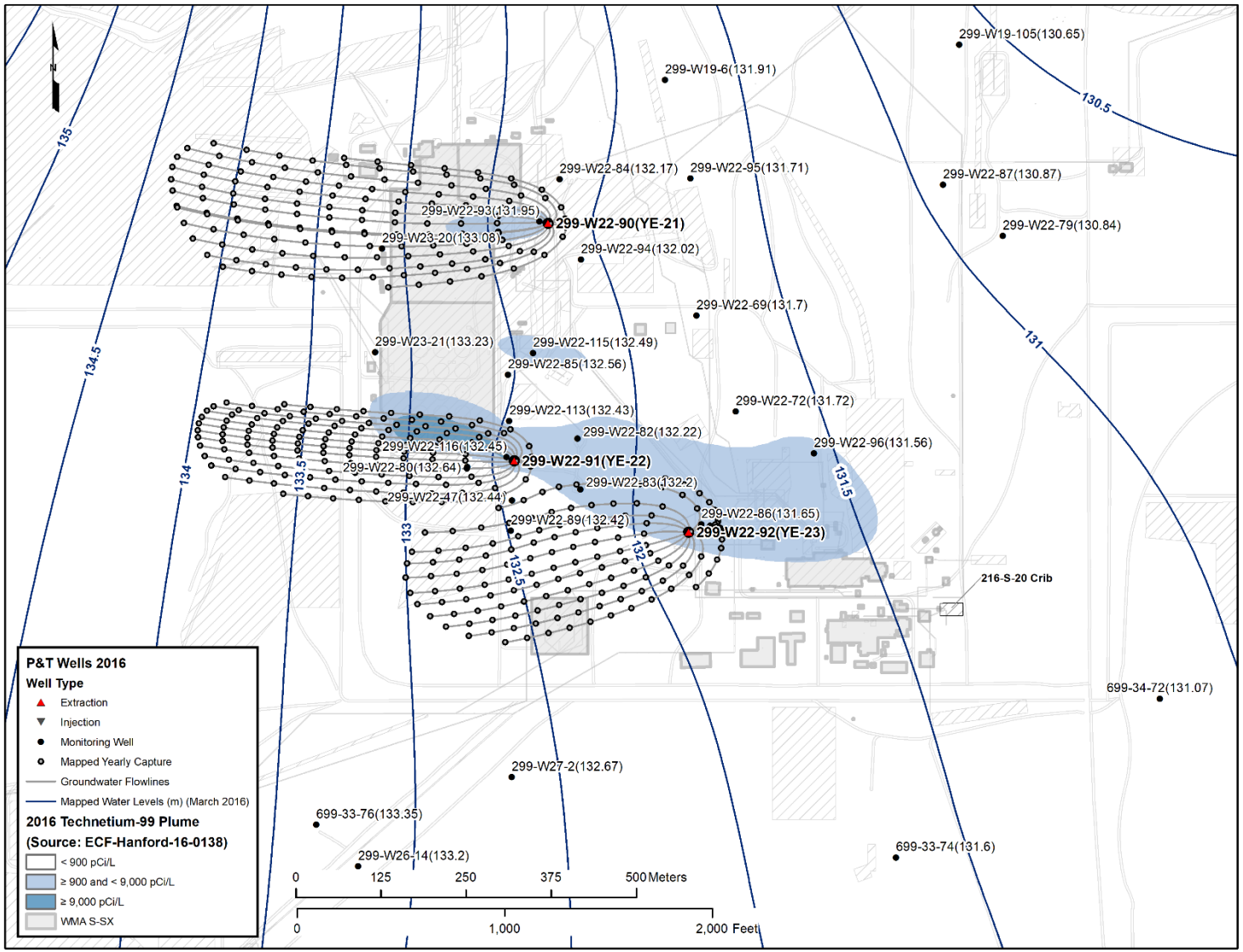


Figure 3-7. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System under March 2016 Conditions (Steady-State Assumption) Compared to the Technetium-99 Plumes

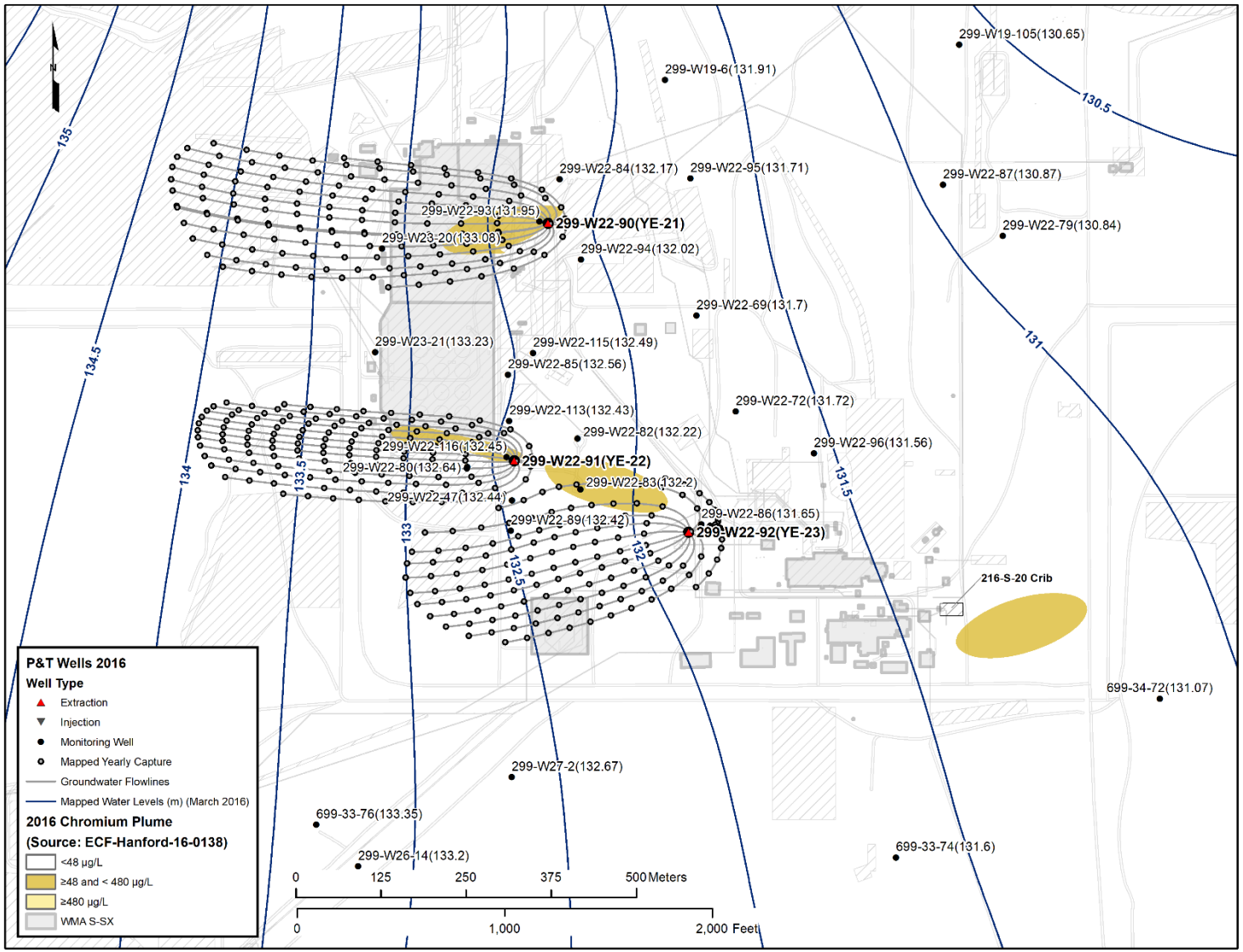


Figure 3-8. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System under March 2016 Conditions (Steady-State Assumption) Compared to the Chromium Plumes

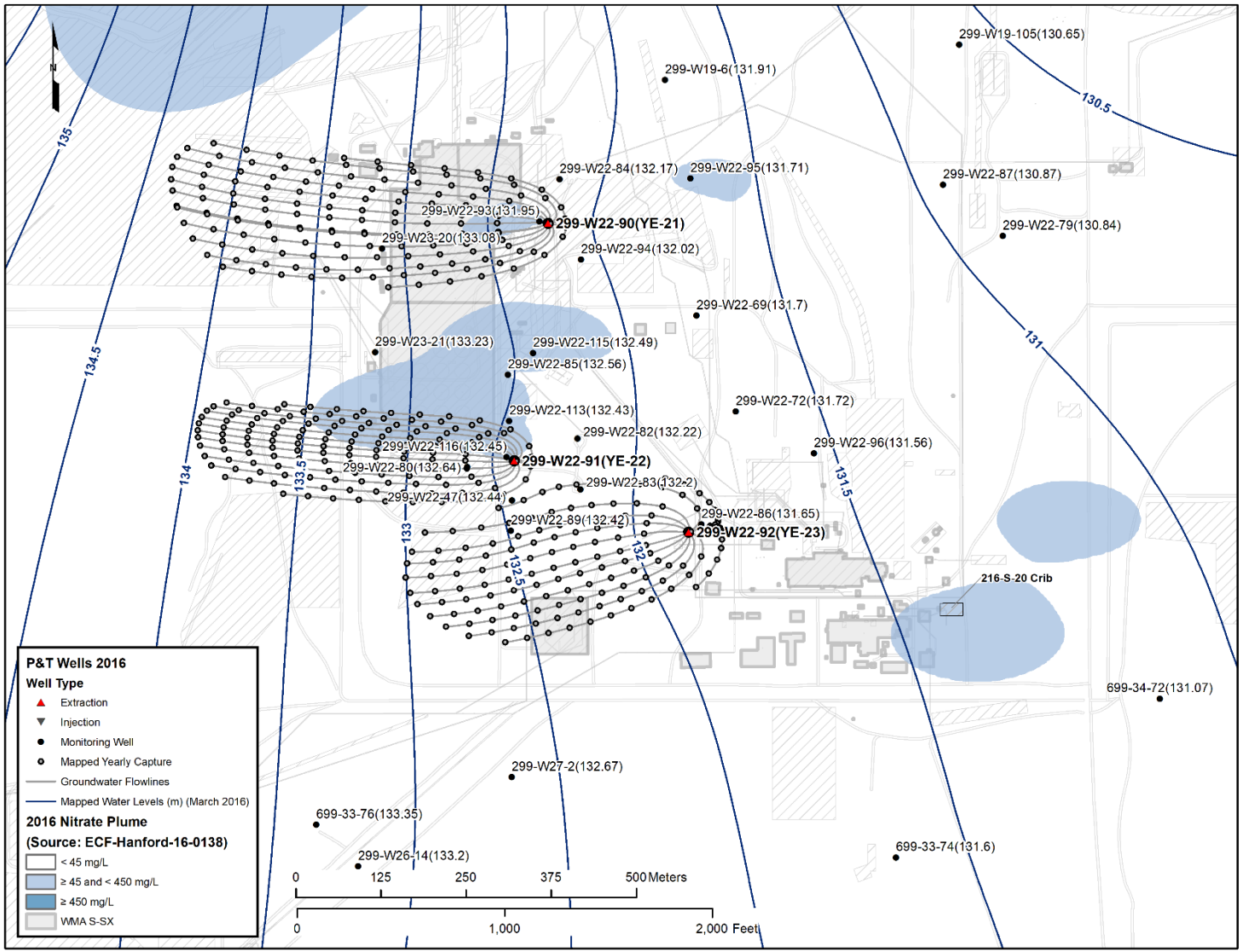


Figure 3-9. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System under March 2016 Conditions (Steady-State Assumption) Compared to the Nitrate Plum

Groundwater contamination baseline conditions from which cleanup progress is evaluated were established during 2012 (Section 2.3.1 of DOE/RL-2013-14, *Calendar Year 2012 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*). In the following subsections, sample results for technetium-99, chromium, nitrate, and carbon tetrachloride during 2016 are presented and compared to baseline concentrations. When more than one sample result was available in a well, the last sample collected during 2016 was used in the comparisons to represent cleanup progress achieved during the year. Depictions of plumes are based on annual average concentrations in the wells and are the same as those presented in DOE/RL-2016-67. Section 2.3.2 of DOE/RL-2013-14 contains background information on the plumes, including sources and historical plume trends.

3.2.3.1 Technetium-99, Chromium, and Nitrate Monitoring Results

Technetium-99, chromium, and nitrate are discussed in this section because they are all mobile tank waste constituents and form similar plumes in groundwater downgradient from the S-SX Tank Farms. Nitrate originated from an upgradient source, the 216-S-25 Crib. Although chromium is listed in the 200-UP-1 ROD (EPA et al., 2012) as two COCs (total chromium and hexavalent chromium), it occurs in Hanford Site groundwater primarily in the mobile hexavalent form. Chromium is analyzed in groundwater samples using two different methods: inductively coupled plasma, which yields a total chromium result (i.e., trivalent and hexavalent combined), and a colorimetric method (ultraviolet/visible light absorption), which yields only the hexavalent form result. Therefore, the Hanford Environmental Information System (HEIS) database includes results for both total and hexavalent chromium, which have different cleanup levels specified in the 200-UP-1 ROD (EPA et al., 2012; 100 and 48 µg/L, respectively). Both chromiums are analyzed when sampling is performed for the 200-UP-1 OU under DOE/RL-2015-14. The 2016 sample data for 200-UP-1 groundwater show that locations exceeding the chromium cleanup levels exceeded the cleanup level for both total and hexavalent chromium. Therefore, for discussion purposes the chromium monitoring results presented in this chapter focuses on the mobile dissolved chromium consisting of sample results for hexavalent chromium and filtered total chromium.

The S and SX Tank Farms are sources of technetium-99, chromium, and nitrate contamination to the groundwater (Figures 3-10, 3-11, and 3-12). The plumes from the S Tank Farm (northern plumes in Figures 3-10, 3-11, and 3-12) extend downgradient (eastward) past well 299-W22-26 (now dry) at concentrations above the respective cleanup levels (900 pCi/L for technetium-99, 48 µg/L for hexavalent chromium, and 45 mg/L for nitrate). Depth-discrete sample results during drilling of extraction well 299-W22-90 indicate that the technetium-99 and nitrate plumes extend to a depth of 5 m (16 ft) below the water table at concentrations above cleanup levels (DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*). A depth to 10 m (33 ft) below the water table is presumed for the hexavalent chromium plume. The technetium-99 plume from the SX Tank Farm (southern plume in Figure 3-10) extends 800 m (2,600 ft) toward the east and southeast from the source. The hexavalent chromium plume extends east from the SX Tank Farm to near well 299-W22-86 (southern plumes in Figure 3-11). Depth-discrete sample results within these plumes indicate that they occur within the upper 20 m (66 ft) of the aquifer at concentrations above cleanup levels (DOE/RL-2009-122). Two extraction wells (299-W22-91 and 299-W22-92) operate within the southern plumes.

The 2016 technetium-99, dissolved chromium, and nitrate sample results from the monitoring wells in the WMA S-SX vicinity are compared to baseline concentrations (i.e., concentrations in the aquifer determined during 2012 prior to operation of the groundwater extraction system) in Tables 3-4, 3-5, and 3-6, respectively. These comparisons are also shown in Figures 3-13 and 3-14, Figures 3-15 and 3-16, and Figures 3-17 and 3-18, respectively. Figures 3-13, 3-15, and 3-17 show bar charts of the 2016 concentrations compared to the baseline 2012 concentrations. Figures 3-14, 3-16, and 3-18 show location of the monitoring wells in relation to the WMA S-SX extraction wells along with pie chart depictions of the 2016 to 2012 concentration comparison for the monitoring wells.

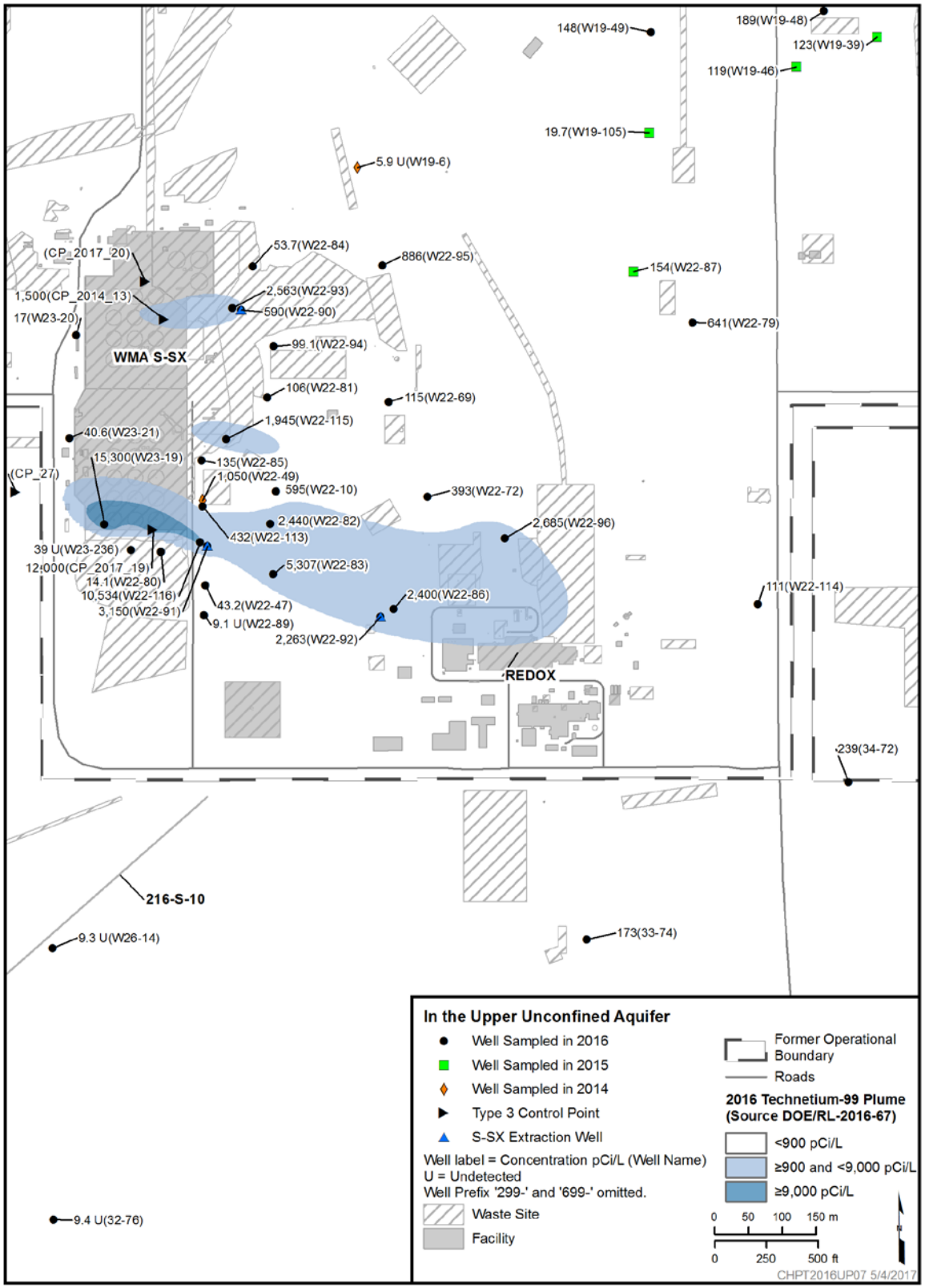


Figure 3-10. Technetium-99 Plumes in Groundwater near the S-SX Tank Farms, 2016

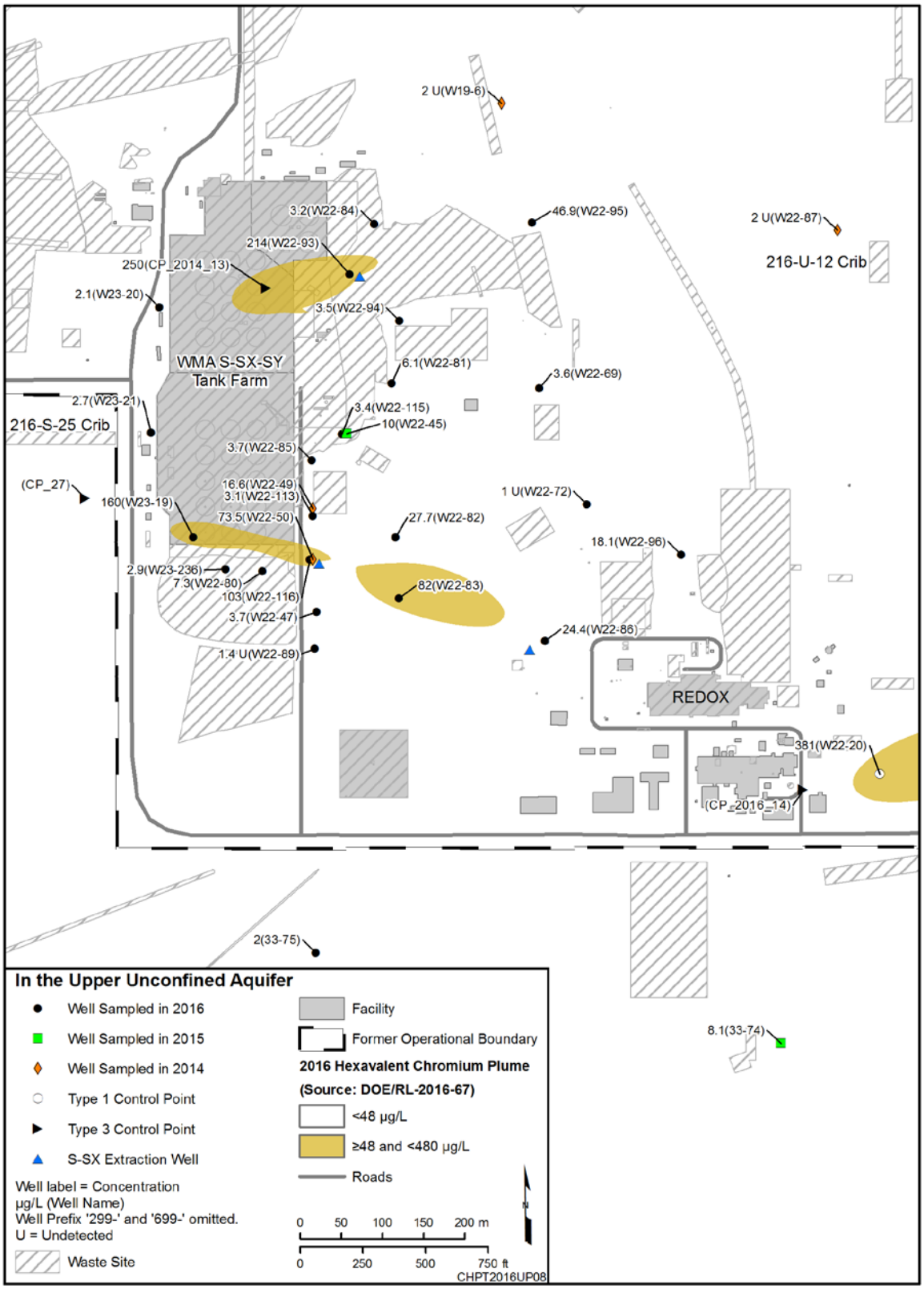


Figure 3-11. Hexavalent Chromium Plumes in Groundwater near the S-SX Tank Farms, 2016

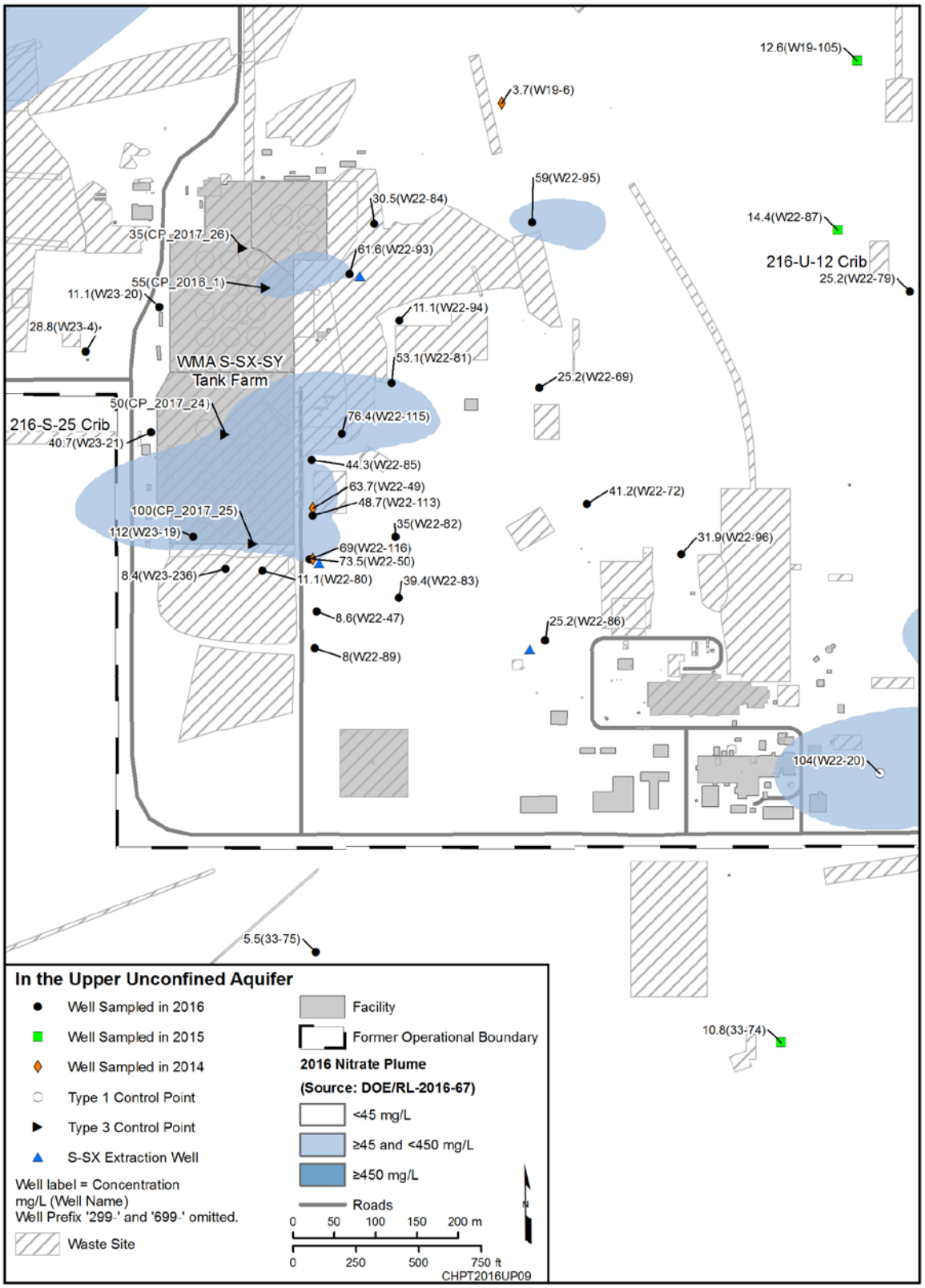


Figure 3-12. Nitrate Plume in Groundwater near the S-SX Tank Farms, 2016

Table 3-4. Comparison of 2016 Technetium-99 Sample Results from Monitoring Wells in the S-SX Tank Farms Vicinity to Baseline Concentrations

Well Name	Baseline (2012) Technetium-99 (pCi/L)	2016 Technetium-99 (pCi/L) [a]	Difference (%) [b]
299-W22-47	15,000	46	-100
299-W22-69	220	115	-48
299-W22-72	135	393	+191
299-W22-80	19	<14.1 [c]	—
299-W22-81	67.5	106	+57
299-W22-82	2,900	2,140	-26
299-W22-83	17,700	4,650	-74
299-W22-84	630	53.7	-92
299-W22-85	140	135	—
299-W22-86	11,000	2,400	-78
299-W22-89	<6.5 [c]	<7.6 [c]	—
299-W22-93 [d]	10,500	4,700	-55 [k]
299-W22-94 [e]	880	99.1	-89 [k]
299-W22-95 [f]	310 [f]	893	+188 [k]
299-W22-96	1,020	2,580	+153
299-W22-113 [g]	2,300	386	-83 [k]
299-W22-115 [h]	520	2,390	+360 [k]
299-W22-116 [i]	5,750	11,200	+95 [k]
299-W23-19	45,000	12,600	-72
299-W23-20	6.70	17	—
299-W23-21	86.2	40.6	—
299-W23-236 [j]	18.0 [j]	<13.9 [c]	— [k]

Note: All replacement wells are located adjacent to dry wells they replaced except for 299-W22-95, which was located about 90 m (300 ft) north of 299-W22-26 because of an anticipated groundwater flow direction change.

a. For wells that were sampled multiple times during 2016, the result shown is from the last sample of the year.

b. Differences are shown for only those wells with a baseline or 2016 sample result at least five times the detection limit (~6.6 pCi/L × 5 = ~33 pCi/L).

c. Less than (<) values reference the minimum detectable activity.

d. Baseline sample result is for 299-W22-44, which is dry. The replacement well is 299-W22-93.

e. Baseline sample result is for 299-W22-48, which is dry. The replacement well is 299-W22-94.

f. Baseline sample result is for 299-W22-26, which is dry. The replacement well is 299-W22-95.

g. Baseline sample result is for 299-W22-49, which is dry. The replacement well is 299-W22-113.

h. Baseline sample result is for 299-W22-45, which is nearly dry. The replacement well is 299-W22-115.

i. Baseline sample result is for 299-W22-50, which is dry. The replacement well is 299-W22-116.

j. Baseline sample result is for 299-W23-15, which is nearly dry. The replacement well is 299-W23-236.

k. 2016 to baseline comparison affected by well design. The replacement wells were installed with 35 ft screens at the water table. The wells they replaced had much shorter saturated screened intervals at the water table because they were becoming dry.

Table 3-5. Comparison of 2016 Chromium Sample Results from Monitoring Wells in the S-SX Tank Farms Vicinity to Baseline Concentrations

Well Name	Baseline (2012) Chromium [a] (µg/L)	2016 Chromium [a] (µg/L) [b]	Difference (%) [c]
299-W22-47	183	4.34	-98
299-W22-69	12.5	3.6	-71
299-W22-72	<5.0 [d]	1.2	—
299-W22-80	25.4	7.3	-71
299-W22-81	9.7	6.1	-37
299-W22-82	32.1	33.6	—
299-W22-83	253	73	-71
299-W22-84	47.5	4.85	-89.8
299-W22-85	6.3	7.2	—
299-W22-86	149	25.8	-82.7
299-W22-89	<5.0 [d]	<4.3 [d]	—
299-W22-93 [e]	353	460	30.3 [l]
299-W22-94 [f]	23.4	5.1	-78.6 [l]
299-W22-95 [g]	9.9	57.9	+484.8 [l]
299-W22-96	5.1	20.6	+303.9
299-W22-113 [h]	8.2	4.1	—
299-W22-115 [i]	8.4	3.5	-58.3 [l]
299-W22-116 [j]	63.7	129	+102.5 [l]
299-W23-19	1,010	168	-83.4
299-W23-20	<5.0 [d]	2.6	—
299-W23-21	6.3	3.98	-36.8
299-W23-236 [k]	6.0	2.89	-52 [l]

Note: All replacement wells are located adjacent to dry wells they replaced except for 299-W22-95, which was located about 90 m (300 ft) north of 299-W22-26 because of an anticipated groundwater flow direction change.

a. Chromium values reflect maximum dissolved chromium (i.e., hexavalent and filtered) sample result.

b. For wells sampled multiple times during 2016, result shown is from the last sample of the year.

c. Differences are shown for only those wells with a baseline or 2016 sample result at least five times the detection limit (i.e., results above an approximation of the quantitation limit). Detection limits were 5 µg/L in 2012 (baseline) and ranged from 1.1 to 10 µg/L in 2016.

d. Less than (<) values reference the detection limit.

e. Baseline sample result is for 299-W22-44, which is dry. The replacement well is 299-W22-93.

f. Baseline sample result is for 299-W22-48, which is dry. The replacement well is 299-W22-94.

g. Baseline sample result is for 299-W22-26, which is dry. The replacement well is 299-W22-95.

h. Baseline sample result is for 299-W22-49, which is dry. The replacement well is 299-W22-113.

i. Baseline sample result is for 299-W22-45, which is nearly dry. The replacement well is 299-W22-115.

j. Baseline sample result is for 299-W22-50, which is dry. The replacement well is 299-W22-116.

k. Baseline sample result is for 299-W23-15, which is nearly dry. The replacement well is 299-W23-236.

l. 2016 to baseline comparison affected by well design. The replacement wells were installed with 35 ft screens at the water table. The wells they replaced had much shorter saturated screened intervals at the water table because they were becoming dry.

Table 3-6. Comparison of 2015 Nitrate Sample Results from Monitoring Wells in the S-SX Tank Farms Vicinity to Baseline Concentrations

Well Name	Baseline (2012) Nitrate (mg/L as NO_3)	2016 Nitrate (mg/L as NO_3) [a]	Difference (%)
299-W22-47	99.4	7.97	-92
299-W22-69	20.7	25.2	+21.7
299-W22-72	29.6	41.2	+39.2
299-W22-80	12.8	11.1	-13.3
299-W22-81	27.4	53.1	+93.8
299-W22-82	62.0	32.8	-47.1
299-W22-83	117	37.2	-68.2
299-W22-84	35.3	30.5	-13.6
299-W22-85	63.7	44.3	-30.5
299-W22-86	70.6	25.2	-64.3
299-W22-89	13.1	7.97	-39.2
299-W22-93 [b]	177	102	-42.4 [i]
299-W22-94 [c]	51.4	5.7	-89.4 [i]
299-W22-95 [d]	39.8	62.0	+55.8 [i]
299-W22-96	18.3	32.8	+79.2
299-W22-113 [e]	84.6	48.7	-42.4 [i]
299-W22-115 [f]	79.2	84.1	+6.2 [i]
299-W22-116 [g]	71.8	70.8	-1.4 [i]
299-W23-19	355	106.0	-70.1
299-W23-20	10.4	11.1	+6.7
299-W23-21	84.6	40.7	-51.9
299-W23-236 [h]	7.24	8.4	16.2 [i]

Note: All replacement wells are located adjacent to dry wells they replaced except for 299-W22-95, which was located about 90 m (300 ft) north of 299-W22-26 because of an anticipated groundwater flow direction change.

a. For wells that were sampled multiple times during 2016, the result shown is from the last sample of the year.

b. Baseline sample result is for 299-W22-44, which is dry. The replacement well is 299-W22-93.

c. Baseline sample result is for 299-W22-48, which is dry. The replacement well is 299-W22-94.

d. Baseline sample result is for 299-W22-26, which is dry. The replacement well is 299-W22-95.

e. Baseline sample result is for 299-W22-49, which is dry. The replacement well is 299-W22-113.

f. Baseline sample result is for 299-W22-45, which is nearly dry. The replacement well is 299-W22-115.

g. Baseline sample result is for 299-W22-50, which is dry. The replacement well is 299-W22-116.

h. Baseline sample result is for 299-W23-15, which is nearly dry. The replacement well is 299-W23-236.

i. 2016 to baseline comparison affected by well design. The replacement wells were installed with 35 ft screens at the water table. The wells they replaced had much shorter saturated screened intervals at the water table because they were becoming dry.

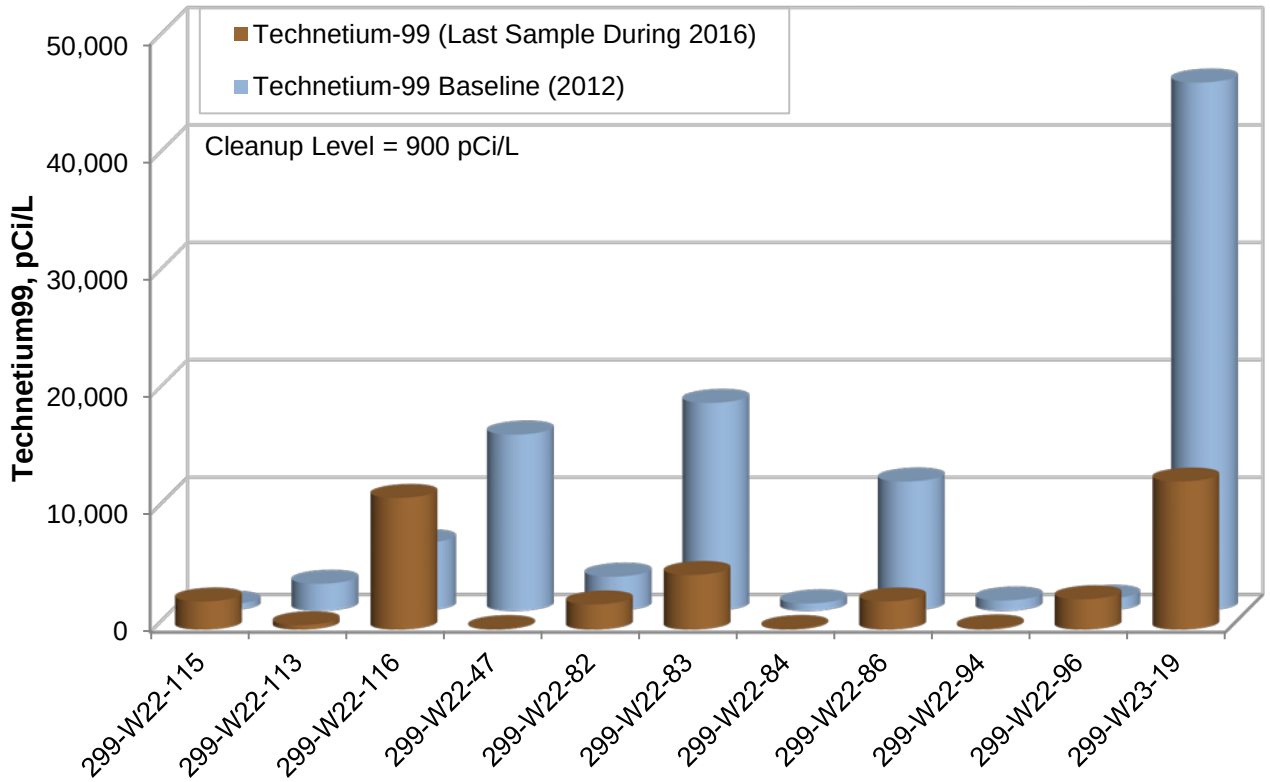


Figure 3-13. Comparison Chart of 2016 Technetium-99 Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

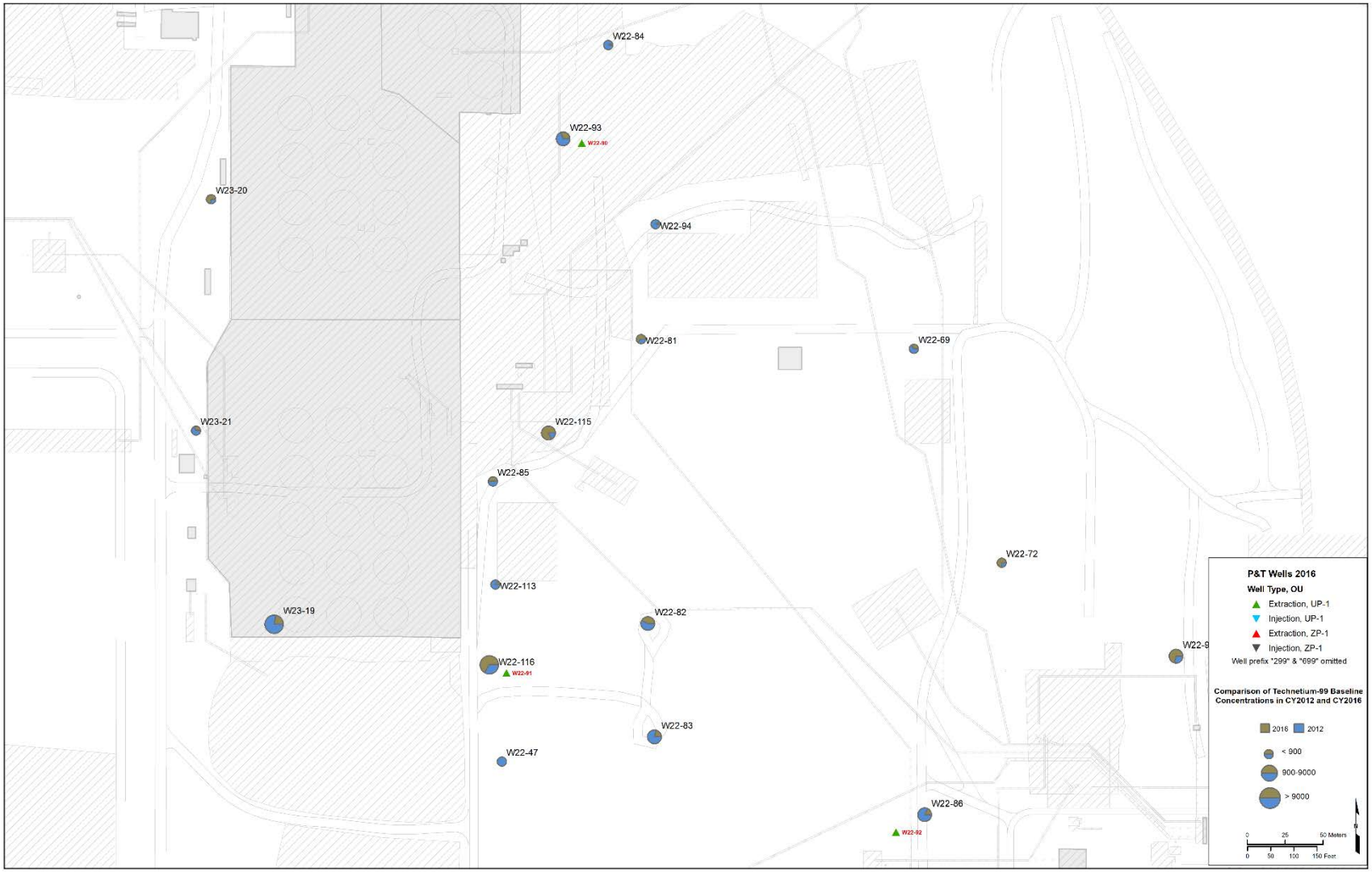


Figure 3-14. Comparison Map of 2016 Technetium-99 Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

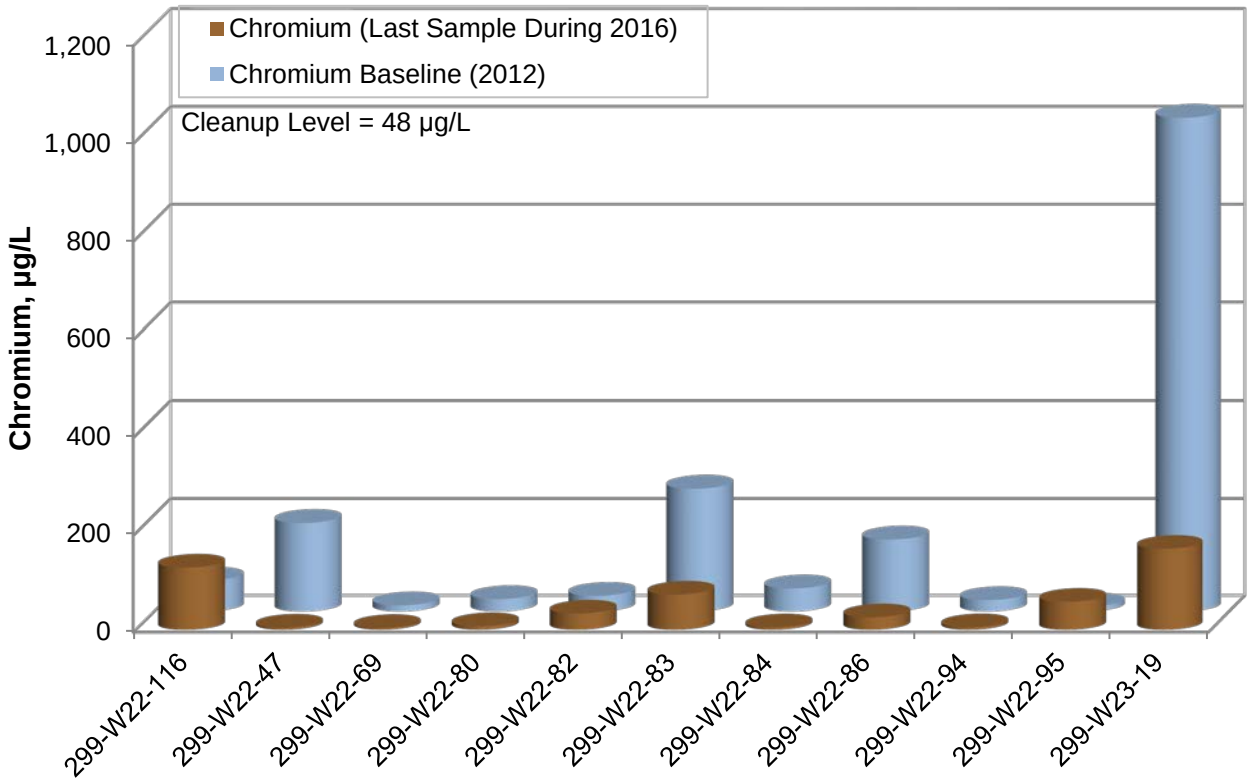


Figure 3-15. Comparison Chart of 2016 Dissolved Chromium Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

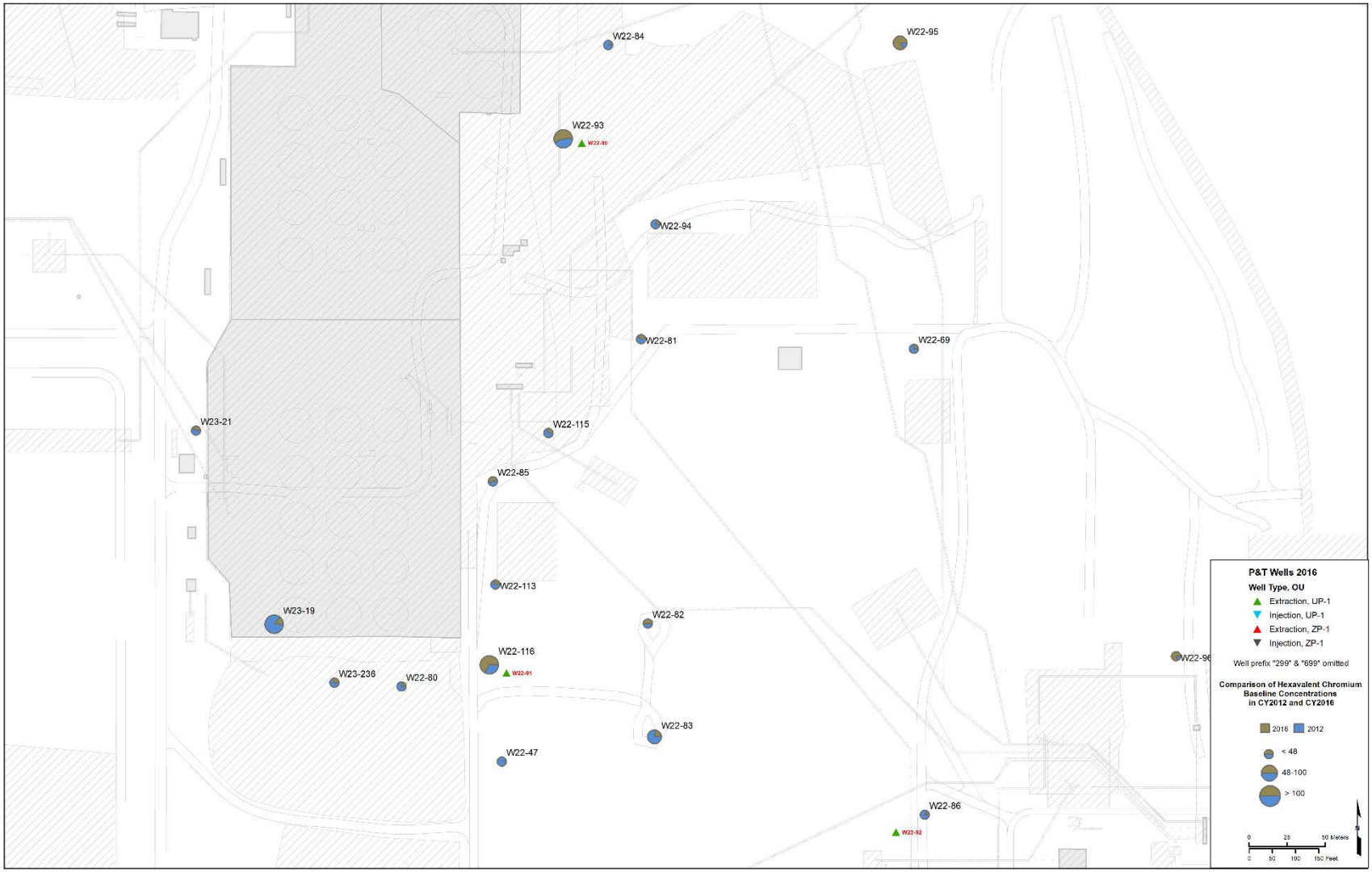


Figure 3-16. Comparison Map of 2016 Dissolved Chromium Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

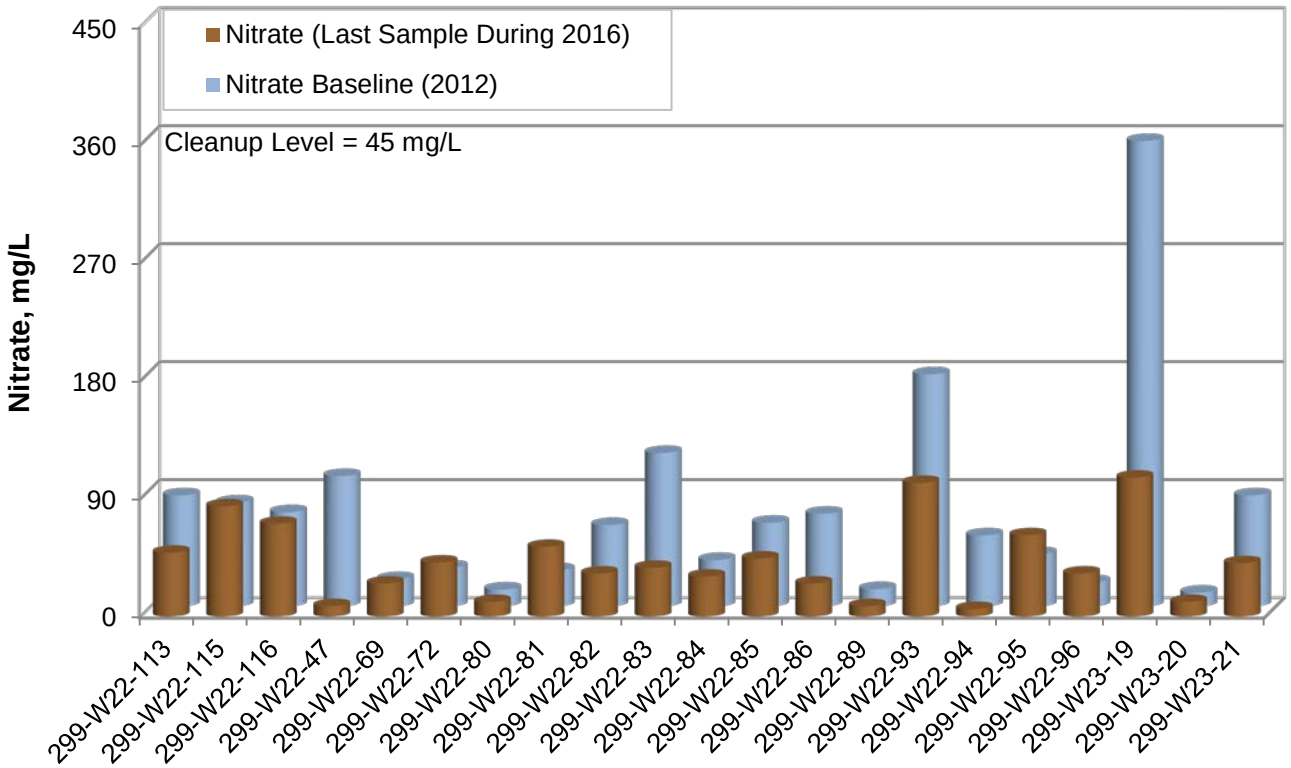


Figure 3-17. Comparison Chart of 2016 Nitrate Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

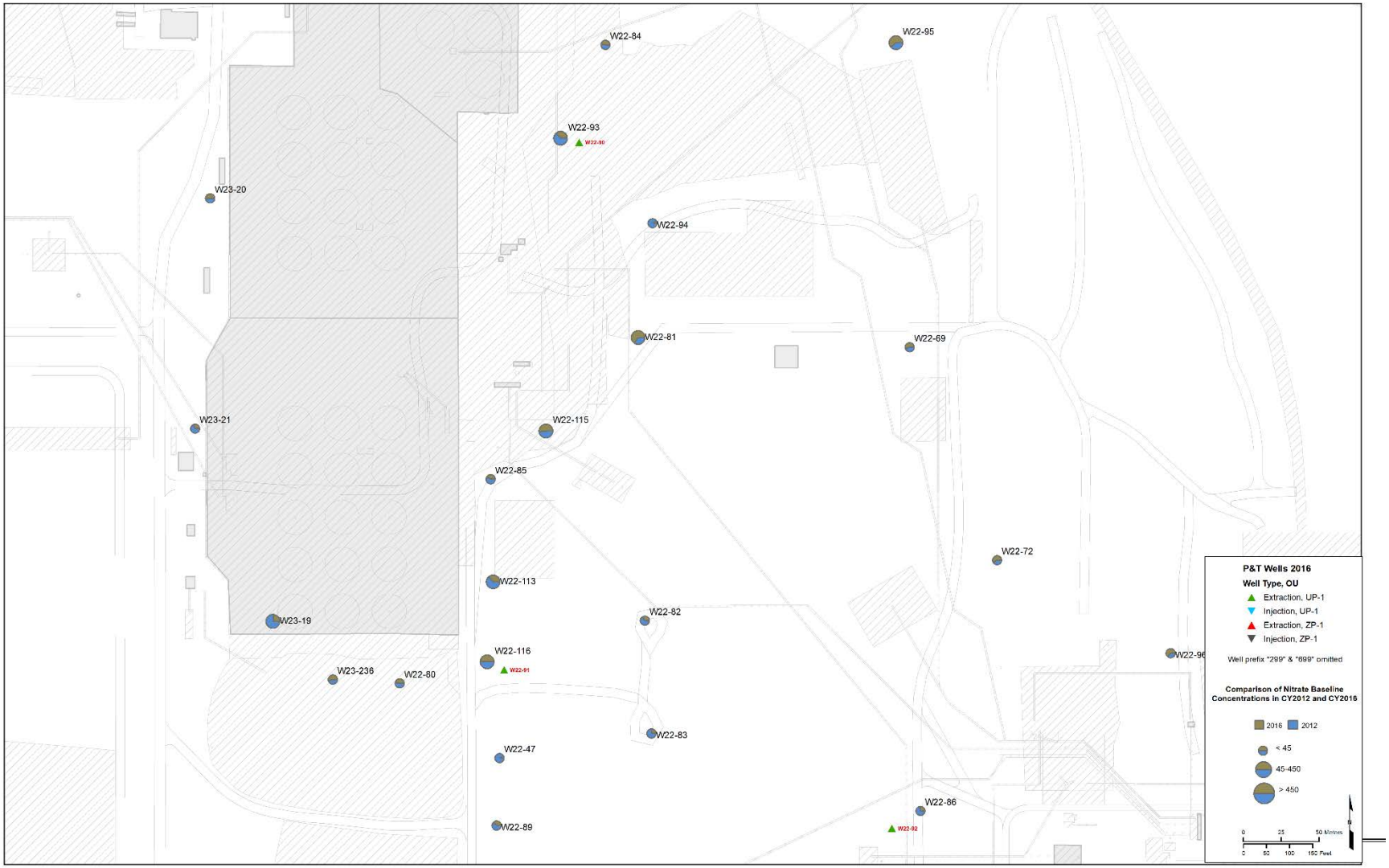


Figure 3-18. Comparison Map of 2016 Nitrate Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

Several WMA S-SX monitoring wells have become dry in recent years or are nearly dry. The following wells have been installed: 299-W22-94 replaced 299-W22-48 and 299-W22-95 replaced 299-W22-26 in 2013; 299-W22-113 replaced 299-W22-49 in 2014; 299-W22-93 replaced 299-W22-44, 299-W22-115 replaced 299-W22-45, 299-W22-116 replaced 299-W22-50, and 299-W23-236 replaced 299-W23-15 in 2015.[2] To evaluate cleanup progress, concentrations in the new wells are compared to the plume baseline concentrations established during 2012 from the corresponding dry wells in Tables 3-4, 3-5, and 3-6 (correlations of a replacement well to the dry well it replaced are given in table footnotes). Comparison to baseline for replaced wells are likely affected by well design. The replacement wells were installed with 35 ft screens at the water table. The wells they replaced had much shorter saturated screened intervals at the water table because they were becoming dry. Concentration decline in sample results between the original and replacement wells may also reflect possible dilution because of the screened interval difference. Concentration increase in sample results between the original and replacement wells may be from plume migration or may also reflect increase contamination with varying depth at new wells. Vertical contamination profile data are not available for the older replaced wells at the depth of the new wells for direct comparison.

Concentrations have declined in a majority of wells that had baseline concentrations above a cleanup level. Concentrations declined in seven of the nine wells with a baseline technetium-99 concentration above the 900 pCi/L cleanup level, in four of the six wells with a baseline dissolved chromium concentration above the 48 µg/L cleanup level for hexavalent chromium, and in 10 of the 12 wells with a baseline nitrate concentration above the 45 mg/L cleanup level. Concentrations declined to below the technetium-99 cleanup level in two wells (299-W22-47 and 299-W22-113), to below the hexavalent chromium cleanup level in two wells (299-W22-47 and 299-W22-86), and to below the nitrate cleanup level in seven wells (299-W22-47, 299-W22-82, 299-W22-83, 299-W22-85, 299-W22-86, 299-W22-94, and 299-W23-21). Concentrations increased above the technetium-99 cleanup level in 299-W22-115, to above the hexavalent chromium cleanup level in 299-W22-95, and above the nitrate cleanup level in two wells (299-W22-81 and 299-W22-95). The increase in 299-W22-95 indicates migration of the portion of the nitrate plume from the S Tank Farm that is downgradient from the capture zone of 299-W22-90.

Concentration changes have been substantial for many of the monitoring wells with a baseline concentration above a cleanup level. For the seven wells with declining technetium-99 concentrations with a baseline concentration above the cleanup level, all but one (299-W22-82 at 26%) of the declines are greater than 50% (ranging from 55% to 100% [Table 3-4]). Concentration declines are not caused by injection of treated groundwater into the aquifer because there are no injection wells operating in the WMA S-SX vicinity. Concentrations increased by 95% in 299-W22-116 located near extraction well 299-W22-91, pumping at an average rate of 130 L/min (34 gpm). The concentration increase in 299-W22-116 indicates that water with high technetium-99 concentration is being drawn into the extraction well. Concentrations have increased by 153% in 299-W22-96 due to downgradient migration of the plume not being captured. The technetium-99 concentration has increased to above the cleanup level at 299-W22-115 (360% increase over baseline).

Concentration changes for dissolved chromium are similar to technetium-99. For the four wells with declining dissolved chromium concentrations that had a baseline concentration above the cleanup level, all have declined by more than 50% (ranging from 71% to 98% [Table 3-5]). Concentrations have increased at 299-W22-116 by 103% for the same reason as technetium-99; water with high dissolved chromium concentration is being drawn into 299-W22-91. Concentrations have increased at 299-W22-95 by 485% (from 9.9 µg/L in 2012 to 57.9 µg/L in 2016) due to the migration of the portion of the hexavalent chromium plume from the S Tank Farm that is downgradient from the capture zone of 299-W22-90 (Figure 3-11).

[2] The replacement wells are located adjacent to the dry wells they replaced except for 299-W22-95, which is located ~90 m (300 ft) north of 299-W22-26 because of an anticipated groundwater flow direction change.

Nitrate concentration decreases have not been as notable. Although declining in 10 of the 12 wells with a baseline concentration above the cleanup level, only six of the wells have declined by greater than 50% (Table 3-6). For all 10 wells, concentration declines range from 30% to 89%. The concentrations at 299-W22-115 and 299-W22-116 are considered stable (less than 20% change compared to baseline). The nitrate plume near the SX Tank Farm is wider than the technetium-99 and hexavalent chromium plumes because nitrate also originated from the 216-S-25 Crib. The wider plume likely accounts for the less substantial concentration declines.

Well 299-W23-19 is located within the SX Tank Farm and has historically had the highest technetium-99 and dissolved chromium concentrations in the OU (Figure 3-19; although 299-W22-93 had a higher dissolved chromium concentration in 2016, Table 3-5). The December 2016 sample results were 12,600 pCi/L for technetium-99 compared to a baseline of 45,000 pCi/L (72% decline), 168 µg/L for dissolved chromium compared to a baseline of 1,010 µg/L (83% decline), and 106 mg/L for nitrate compared to the baseline of 355 mg/L (70% decline). This well is located within the source area, and concentrations have varied over time (Figure 3-19), presumed due to variations in the mass flux of contamination entering the aquifer from the vadose zone. The most recent concentration declines may indicate a reduction in the mass flux, but the declines are most likely caused by an increased groundwater flow velocity beneath the tank farm resulting from operation of the groundwater extraction system. Drawdown from the extraction wells has increased the hydraulic gradient beneath the SX Tank Farm, resulting in a higher groundwater flow rate. The calculated average flow rate for 2016 is 66 m/yr (215 ft/yr; DOE/RL-2016-67), which is greater than the 35 m/yr (110 ft/yr) flow rate prior to operation of the groundwater extraction system (DOE/RL-2013-22, *Hanford Site Groundwater Monitoring Report for 2012*). A higher flow rate means that contamination entering the aquifer from the vadose zone would mix into a larger volume of water, resulting in lower concentrations.

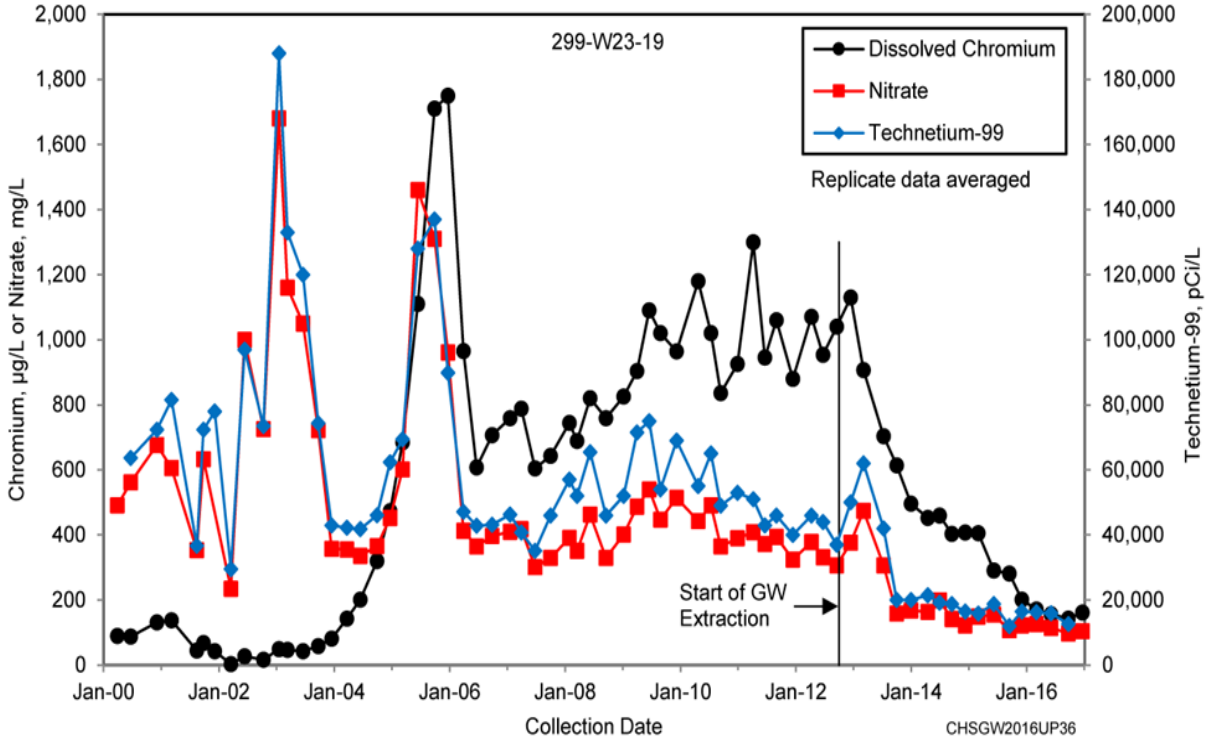


Figure 3-19. Technetium-99, Dissolved Chromium, and Nitrate Concentrations in Well 299-W23-19 within the SX Tank Farm

Concentrations in the northern plume extraction well (299-W22-90) have declined since startup of pumping in 2012 (Figures 3-20, 3-21, and 3-22). The technetium-99 concentration has declined by 92% from 7,010 pCi/L in August 2012 to 559 pCi/L in August 2016, the dissolved chromium concentration has declined by 92% from 403 to 33 μg/L, and the nitrate concentration has declined by 77% from 113 to 25.7 mg/L. Concentrations in adjacent monitoring well 299-W22-93 are higher than in the extraction well. Well 299-W22-93 is a replacement for 299-W22-44, and sample results during 2016 were 4,700 pCi/L for technetium-99, 460 μg/L for dissolved chromium, and 102 mg/L for nitrate, all above their respective cleanup levels. The lower concentrations in the extraction well are caused by concentration averaging because the capture zone for the well is larger than the plumes. Thus, in addition to water from within the plumes being drawn into the extraction well, water from outside the plumes (laterally and vertically) is also being drawn in diluting the plume concentrations. Except for dissolved chromium, concentrations in 299-W22-93 are substantially lower than the baseline sample results from 299-W22-44 (Tables 3-4, 3-5, and 3-6), indicating good progress in remediating the plumes.

Technetium-99, dissolved chromium, and nitrate concentrations in the southern plume extraction wells (299-W22-91 and 299-W22-92) also declined but not as much as the concentrations at 299-W22-90 (Figures 3-20, 3-21, and 3-22). The ratio between plume areal extent and size of the capture zone is larger for 299-W22-91 and 299-W22-92 than for 299-W22-90 (Figures 3-7, 3-8, and 3-9); thus, there is less dilution at 299-W22-91 and 299-W22-92 as water from outside the plumes (laterally and vertically) is drawn into the wells. The technetium-99 concentration continued to stay below the cleanup level in 299-W22-90 during 2016 (August 2016 sample result was 559 pCi/L). Dissolved chromium concentrations continued to stay below the 48 μg/L cleanup level in 299-W22-90, 299-W22-91, and 299-W22-92 during 2016 (the 2016 sample results were 33, 31 and 28 μg/L, respectively).

3.2.3.2 Carbon Tetrachloride Monitoring Results

Cleanup of carbon tetrachloride is not an objective of the U Plant remedy, but the extraction wells do remove carbon tetrachloride from the aquifer and so contribute to the overall larger remedy for this constituent. For information purposes, carbon tetrachloride monitoring results in the U Plant area wells are provided in this section. See Chapter 4 for an evaluation of the larger carbon tetrachloride remedy.

Carbon tetrachloride is widespread throughout the area surrounding the S and SX Tank Farms (Figure 3-23) and throughout the 200 West Area (Chapter 4, Figure 4-8). This constituent originated from sources associated with the PFP, which overlies the 200-ZP-1 OU. Much of the carbon tetrachloride within 200-UP-1 likely migrated into the OU from waste sites overlying the 200-ZP-1 OU, but some carbon tetrachloride may also have originated from the U Pond located west of the S and SX Tank Farms (U Pond received some waste streams from the PFP).

The 2016 carbon tetrachloride sample results from monitoring wells in the WMA S-SX vicinity are compared to baseline concentrations in Table 3-7 and Figure 3-24. Of these wells, 11 of 15 were not sampled in 2016 as they are not sampled annually. Trends in carbon tetrachloride concentrations are mixed. For example, a substantial decline has occurred in 299-W22-86, while a substantial increase has occurred at 299-W22-72 (Figure 3-25). The June 2016 sample result for 299-W22-86 was 16.3 μg/L compared to a baseline of 90.5 μg/L (82% decline). Well 299-W22-86 is located near extraction well 299-W22-92 and the decrease in concentration reflects mass removal and dilution resulting from groundwater extraction. Well 299-W22-72 is over 200 m (650 ft) from the WMA S-SX extraction wells and not influence directly by the extraction wells; however, the overall water table in the region is declining. The concentration in 299-W22-72 was 69.4 μg/L in June 2016 compared to a baseline of 23.8 μg/L (192% increase).

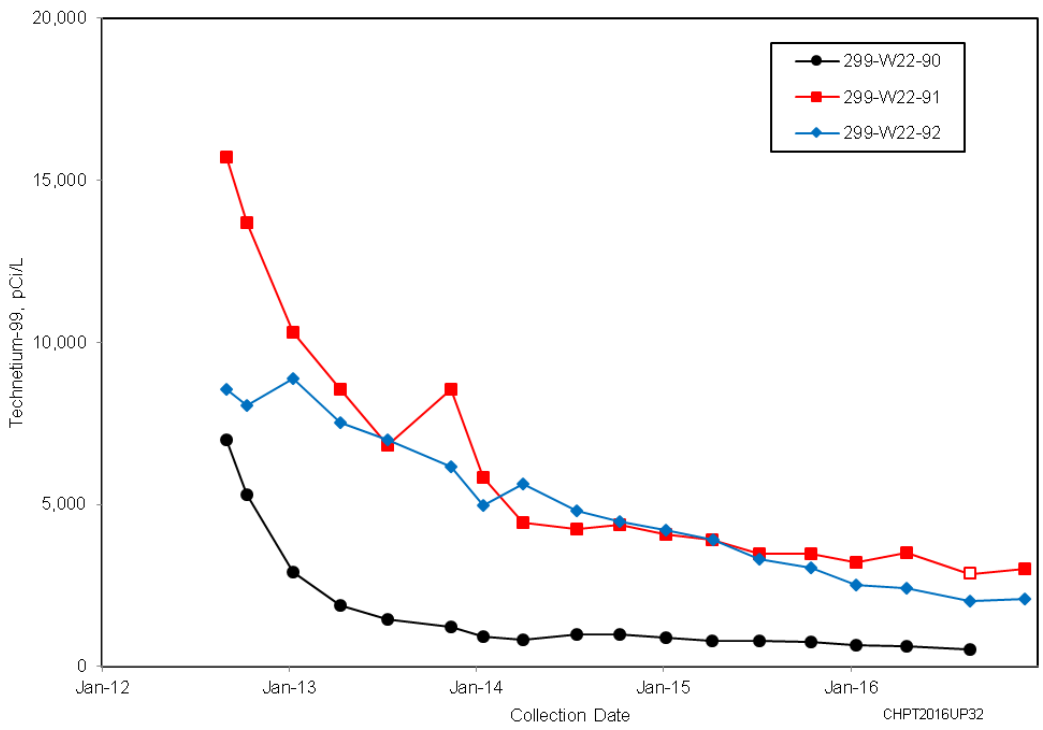


Figure 3-20. Technetium-99 Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

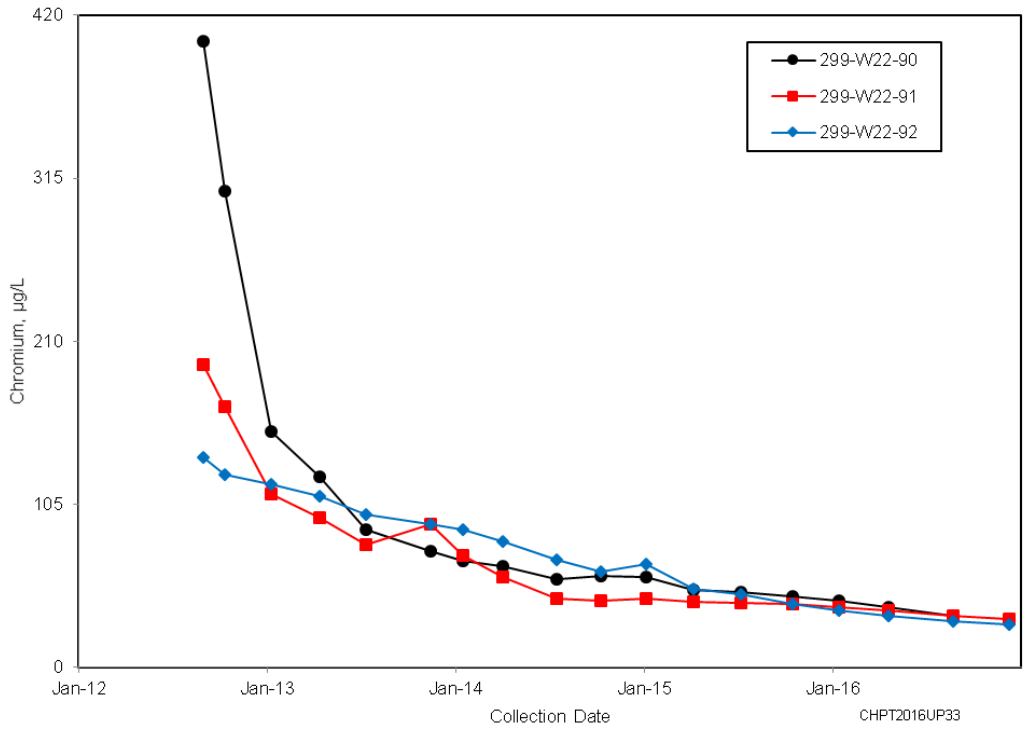


Figure 3-21. Dissolved Chromium Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

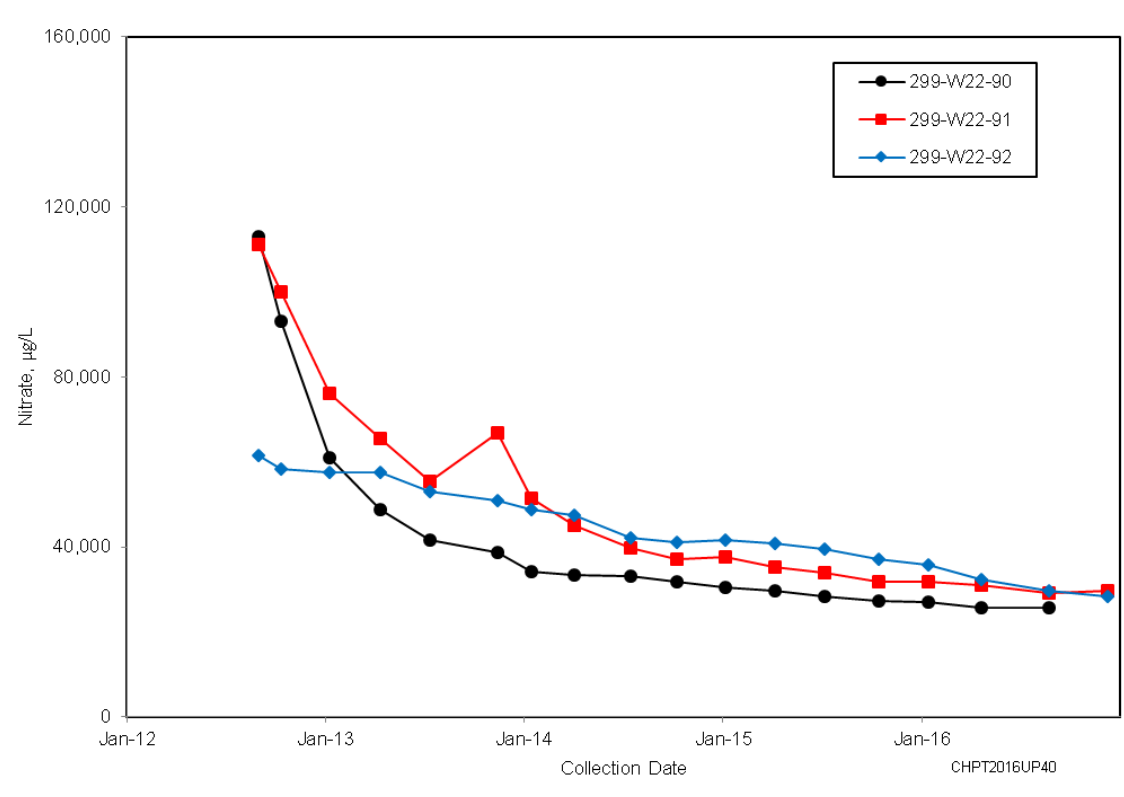


Figure 3-22. Nitrate Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

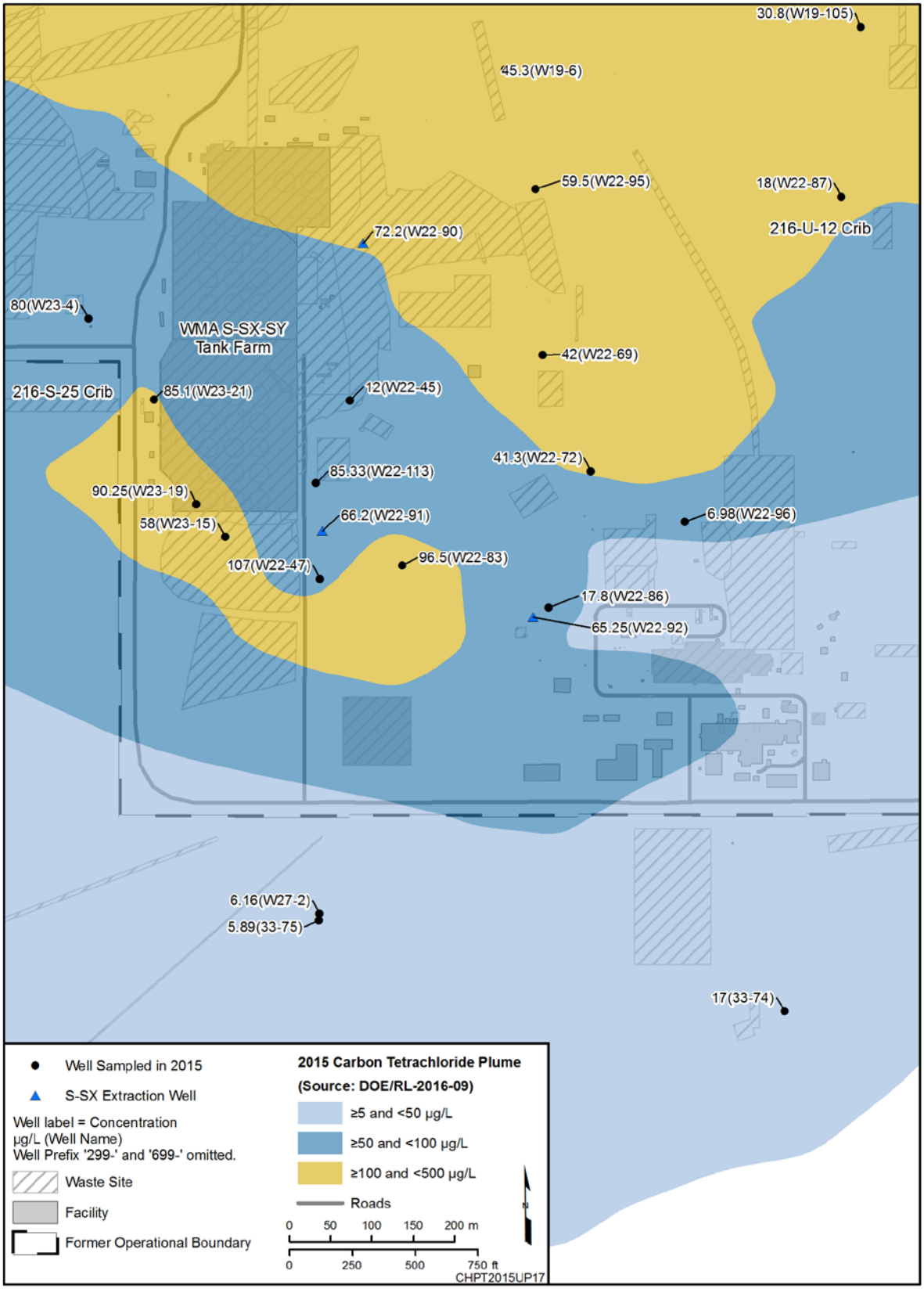


Figure 3-23. Carbon Tetrachloride Plume in Groundwater near the S-SX Tank Farms, 2016

Table 3-7. Comparison of 2016 Carbon Tetrachloride Sample Results from Monitoring Wells in the S-SX Tank Farms Vicinity to Baseline Concentrations

Well Name	Baseline (2012) Carbon Tetrachloride (µg/L)	2016 Carbon Tetrachloride (µg/L) [a]	Difference (%) [b]
299-W22-45	78	Not sampled	—
299-W22-47	105	128	+23
299-W22-69	24	Not sampled	+75
299-W22-72	23.8	69.4	+192
299-W22-83	90	Not sampled	—
299-W22-86	90.5	16.3	-82
299-W22-93 [c]	13	Not sampled	—
299-W22-94 [d]	1.20	Not sampled	—
299-W22-95 [e]	67	Not sampled	—
299-W22-96	4.4	Not sampled	—
299-W22-113 [f]	59	Not sampled	+64
299-W22-116 [g]	82	Not sampled	—
299-W23-15	73.5	Not sampled	—
299-W23-19	84	84.4	+0.5
299-W23-21	113	Not sampled	—

Note: All of the replacement wells are located adjacent to the dry wells they replaced, except for 299-W22-95. This well was located about 90 m (300 ft) north of 299-W22-26 because of an anticipated groundwater flow direction change.

a. For wells that were sampled multiple times during 2016, the result shown is from the last sample of the year.

b. Differences shown are for only those wells with a baseline or 2016 sample result at least five times the detection limit (1 µg/L × 5 = 5 µg/L; i.e., results above an approximation of the quantitation limit).

c. Baseline sample result is for 299-W22-44, which is dry. The replacement well is 299-W22-93.

d. Baseline sample result is for 299-W22-48, which is dry. The replacement well is 299-W22-94.

e. Baseline sample result is for 299-W22-26, which is dry. The replacement well is 299-W22-95.

f. Baseline sample result is for 299-W22-49, which is dry. The replacement well is 299-W22-113.

g. Baseline sample result is for 299-W22-50, which is dry. The replacement well is 299-W22-116.

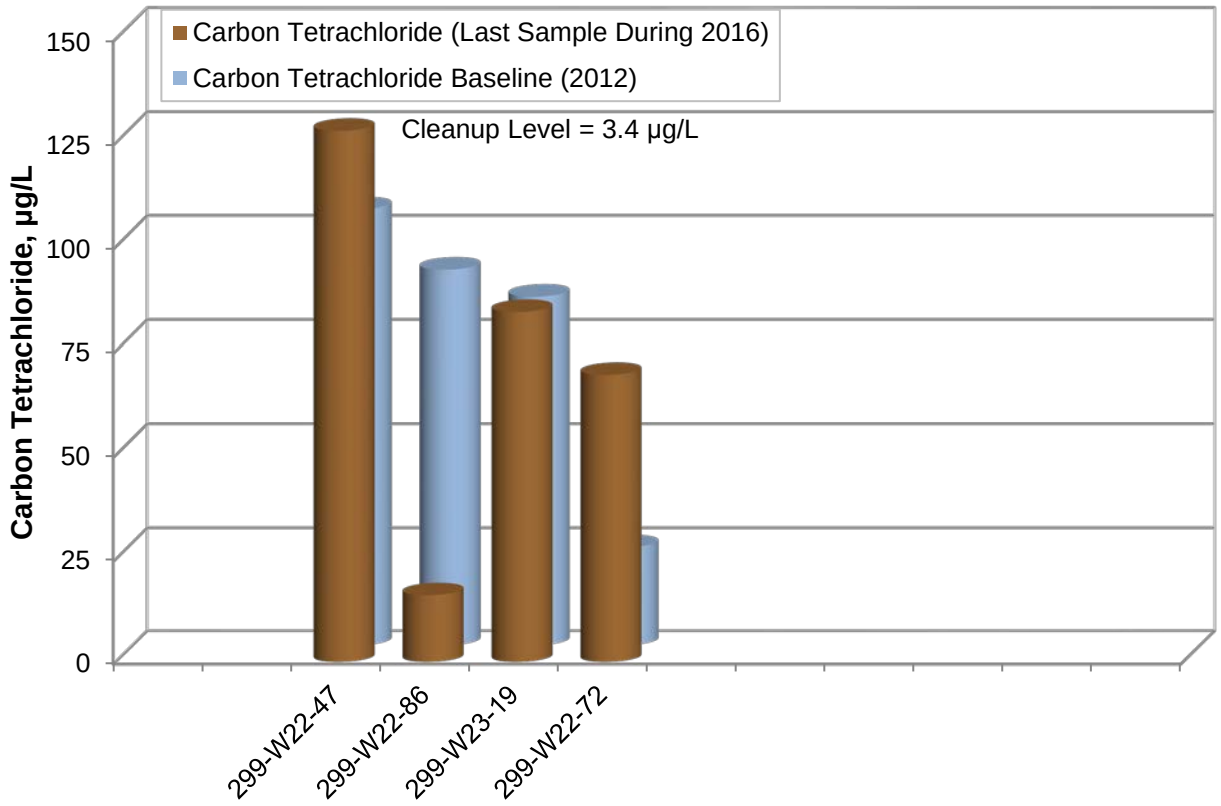


Figure 3-24. Comparison of 2016 Carbon Tetrachloride Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

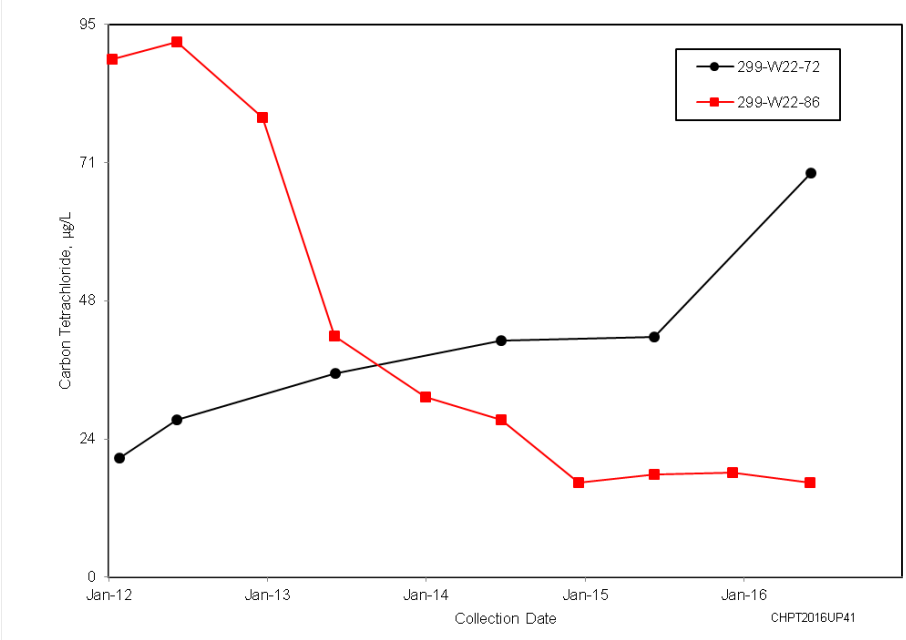


Figure 3-25. Carbon Tetrachloride Concentrations in Wells 299-W22-86, and 299-W22-72

In the extraction wells, the carbon tetrachloride concentration response to pumping differs from that of the other constituents. Concentrations increased in 299-W22-90 during 2012 and 2013, but they have been generally stable since that time (Figure 3-26). Concentrations in wells 299-W22-91 and 299-W22-92 had been declining but were generally stable in 2016 (Figure 3-26). The maximum concentration during 2016 was 83 µg/L in the January sample from 299-W22-90. As a result of the widespread distribution of carbon tetrachloride in the aquifer, smaller carbon tetrachloride concentration changes are seen as the capture zones grow in lateral and vertical extent.

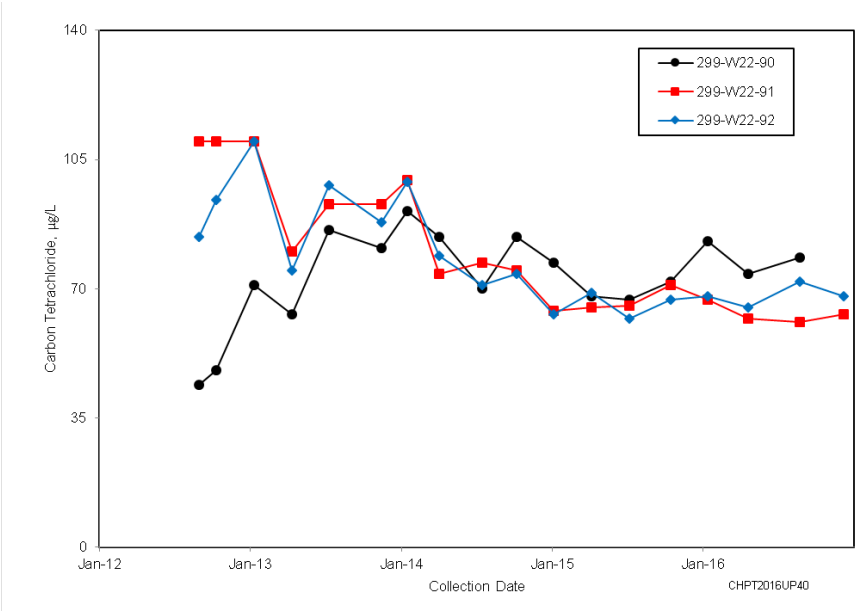


Figure 3-26. Carbon Tetrachloride Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

3.2.3.3 Performance Monitoring Calculations

Progress toward achieving the technetium-99 cleanup level at WMA S-SX was also evaluated by calculating the one-sided UCL_{95} on the mean plume concentration, as described in DOE/RL-2013-07 and DOE/RL-2015-14. This was done for technetium-99 because it is the primary COC for which the groundwater extraction system was designed. Annual UCL_{95} values were calculated beginning in 2008, 4 years prior to startup of the WMA S-SX groundwater extraction system in 2012. The calculations used a minimum of 20 sample results, and data from the previous 2 years were used as needed to ensure that a sufficient number of samples were available. The wells used for the calculation are identified in DOE/RL-2015-14 and are primarily within the baseline plume footprint (i.e., have baseline concentrations above the 900 pCi/L cleanup level).

UCL_{95} calculations for measured groundwater concentrations for 2008 through 2016 are shown in Figure 3-27. The average technetium-99 UCL_{95} value prior to startup of groundwater extraction was 20,200 pCi/L, and the trend was mostly stable. The UCL_{95} value has declined since groundwater extraction began during 2012. The 2016 value was 9,430 pCi/L indicating substantial progress in reducing the mean plume concentration.

3.3 U Plant Area P&T System

The uranium plume near U Plant originated from the 216-U-1 and 216-U-2 Cribs, which received nearly 16 million L (4.2 million gal) of effluent between 1951 and 1967 containing an estimated 4,000 kg of uranium (ARH-CD-745, *Input and Decayed Values of Radioactive Liquid Wastes Discharged to the Ground in the 200 Areas Through 1975*). These cribs were also a source of technetium-99 and nitrate to groundwater. Late in their service life, the cribs received acidic waste that mobilized the uranium in the vadose zone. Effluent disposed to the nearby 216-U-16 Crib in 1984 and 1985 migrated north along the Cold Creek unit as perched water and transported the mobilized uranium beneath the 216-U-1 and 216-U-2 Cribs, adding mass to the groundwater plume (WHC-EP-0133, *U1/U2 Uranium Plume Characterization, Remedial Action Review and Recommendation for Future Action*). The uranium plume is interpreted to extend 1.5 km (0.9 mi) to the east of the cribs at levels above the 30 μg/L cleanup level (Figure 3-28).

The selected remedy for the plumes in the U Plant area is a combination of groundwater extraction and treatment and MNA (EPA et al., 2012). The U Plant area P&T system consists of two extraction wells (299-W19-113 and 299-W19-114) and aboveground, dual-walled pipelines to convey extracted groundwater to the 200 West P&T radiological building for treatment.

The U Plant area P&T system began operating during September 2015. Extracted groundwater is pumped to the 200 West P&T which consists of two main processes:

- Radiological pretreatment process using IX resins
- Central treatment process that uses anoxic and aerobic biodegradation for nitrate, metals, and organic contaminants; membrane filtration to remove particulate matter; and air stripping to remove VOCs

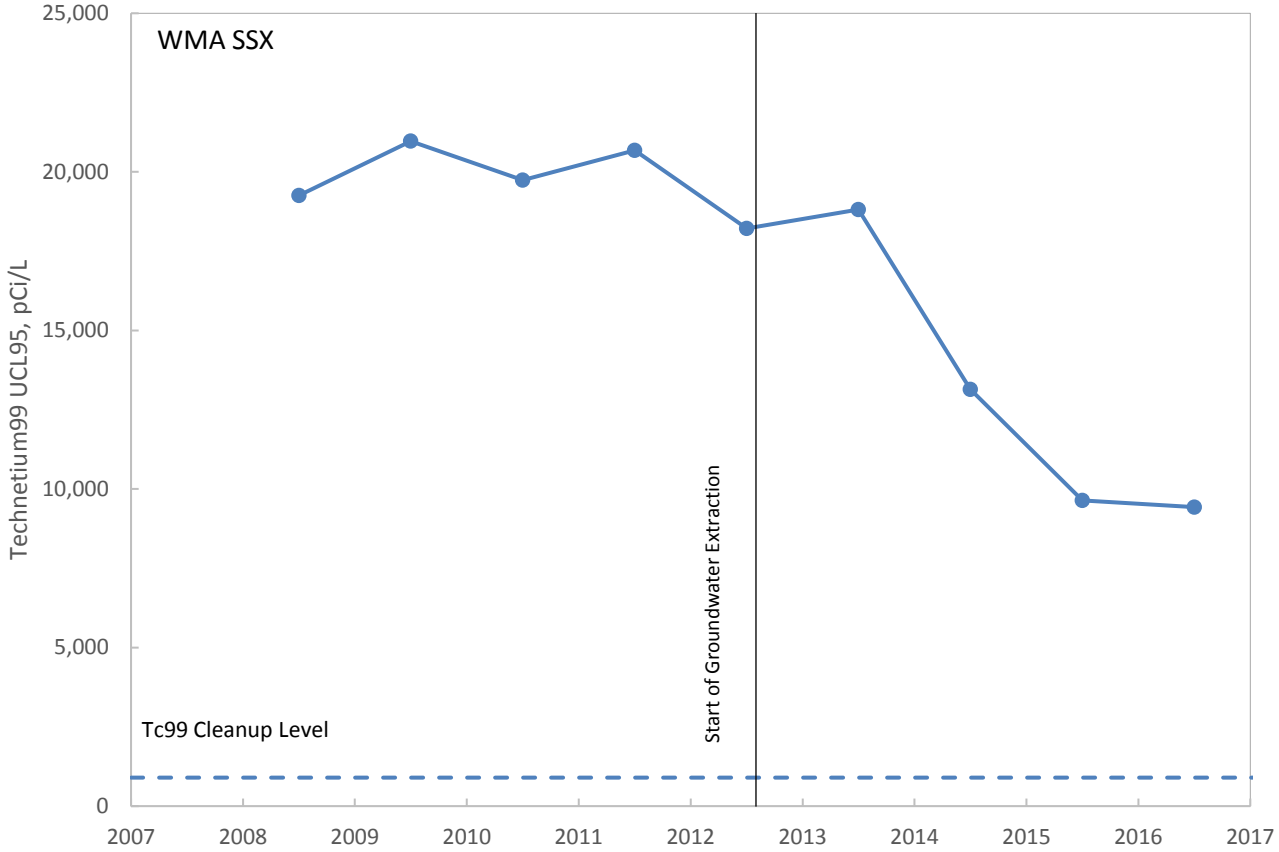


Figure 3-27. Upper Confidence Limits (95th Percentile) on the Mean Concentration of Technetium-99 for the WMA S-SX Groundwater Extraction System

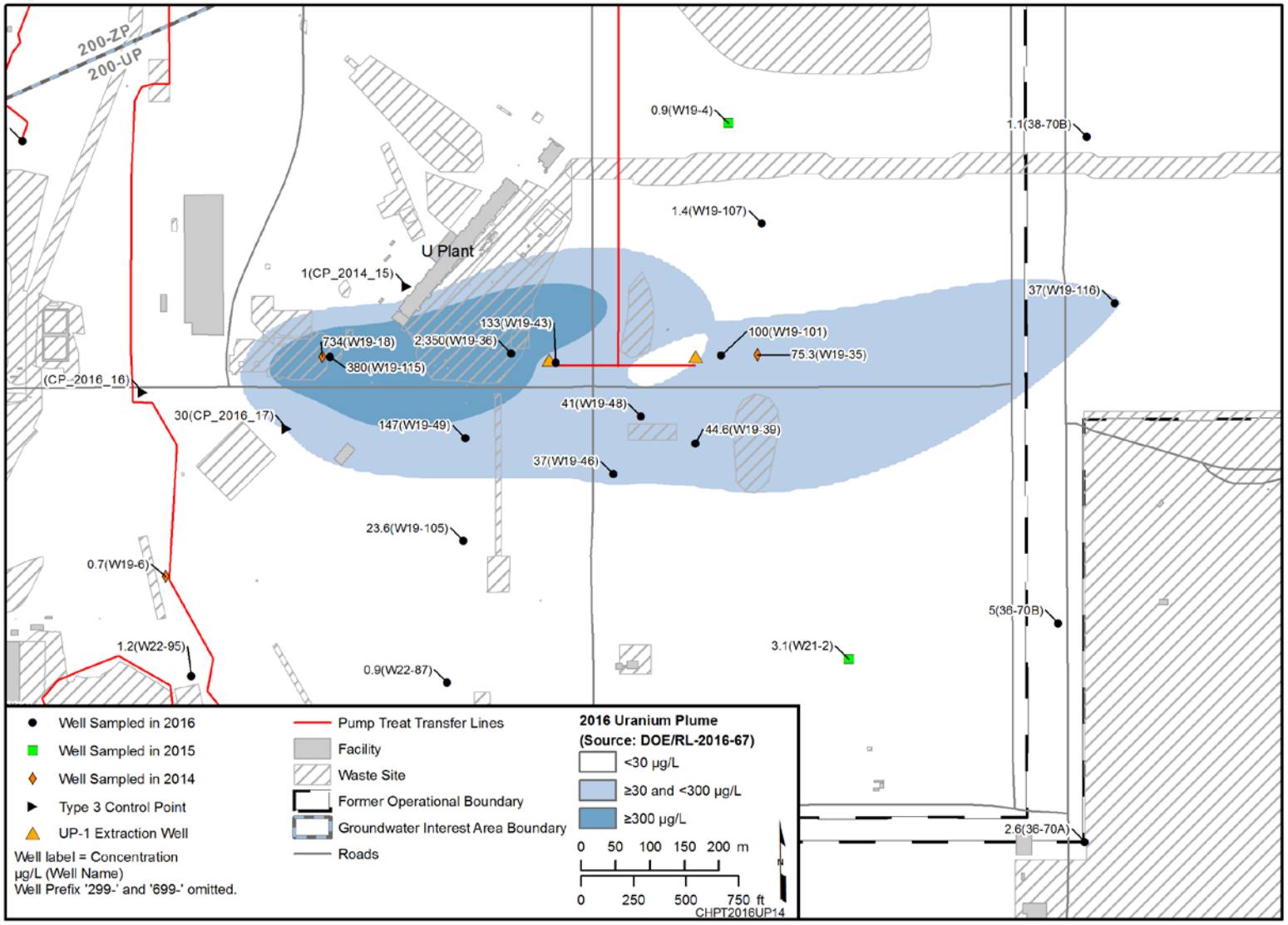


Figure 3-28. U Plant Area P&T System and the Uranium Plume, 2016

Groundwater from the U Plant area extraction wells is combined with groundwater from 299-E33-268, a uranium plume extraction well in the 200-BP-5 OU in the 200 East Area (Chapter 6). The water from these wells then passes through the uranium IX treatment train. The water is combined with water from 200-ZP-1 OU extraction wells requiring radiological treatment and sent through another IX resin to remove technetium-99 (and low concentrations of iodine-129). The effluent from this process is then combined with groundwater from the remaining extraction wells (not requiring radiological treatment) and passed through the central treatment process. The treated water is returned to the aquifer using injection wells. The treatment system is further described in Chapter 2, Section 2.1.

The current U Plant area P&T system is the third system used for remediating the plumes from the 216-U-1 and 216-U-2 Cribs. The first system operated from June 13, 1985 to November 26, 1985 in the vicinity of the cribs (WHC-EP-0133). It removed 687 kg of uranium from the groundwater by an IX treatment system. The second was an interim action system that began operating as a treatability test in March 1994 and continued until March 2011. The system was focused on the area south and southeast from U Plant (~300 to 600 m [1,000 to 2,000 ft] downgradient from the cribs). The extraction wells varied, but 299-W19-36 and 299-W19-43 were used during the later years of system operation. A rebound study was conducted between January 2005 and January 2006, and the system was restarted in April 2007 (DOE/RL-2008-02, *200-UP-1 and 200-ZP-1 Operable Units Pump and Treat System Annual Report for FY07*). The system removed a total of 220.5 kg of uranium from the aquifer (DOE/RL-2012-03, *Calendar Year 2011 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*).

The following sections describe operation of the current (i.e., the third) P&T system along with results of water level and contaminant monitoring.

3.3.1 Remedial System Operation

The U Plant area P&T system operated greater than 99% of the time in 2016. The extraction wells were periodically shut down for system maintenance, but all of these instances lasted less than 1 day. Water was pumped from the aquifer every day during 2016.

Data used to monitor remedial system operation consist of flow rates from the extraction wells, sample results from the extraction wells, and influent/effluent sample results from the treatment system.

3.3.1.1 Extraction Well Flow Rates

The U Plant area P&T system was designed to operate at a nominal combined flow rate of 568 L/min (150 gpm). Average flow rates of 203 L/min (53.6 gpm) for 299-W19-113 and 368 L/min (97.3 gpm) for 299-W19-114 were achieved during 2016. This yielded an annual average combined flow rate of 571 L/min (151 gpm). The total volume of water extracted from the aquifer during 2016 was 301 million L (80 million gal).

3.3.1.2 Extraction Well Mass Removal

The U Plant area P&T extraction wells are sampled quarterly, and were sampled in January, April, August, and December 2016. The results of this sampling are provided in Table 3-8. The sample results and the extraction well flow rates were used to estimate the total mass (or activity) of uranium, technetium-99, nitrate, and carbon tetrachloride removed from the aquifer, and these are provided in Table 3-9.

Table 3-8. Extraction Well Sample Results for the U Plant Area P&T System

Well Name	Constituent	01/12/2016 Result	04/19/2016 Result	08/25/2016 Result	12/07/2016 Result
299-W19-113 (YE-25)	Carbon tetrachloride (µg/L)	97	110	91	100
	Uranium (µg/L)	24	24	49	82
	Nitrate (mg/L as NO_3)	487	301	226	181
	Technetium-99 (pCi/L)	5,670	3,660	3,010	2,690
299-W19-114 (YE-26)	Carbon tetrachloride (µg/L)	79	76	61	67
	Uranium (µg/L)	26	24	30	27
	Nitrate (mg/L as NO_3)	106	97.4	93	84.1
	Technetium-99 (pCi/L)	460	424	407	414

Table 3-9. Contaminant Mass (or Activity) Removed from the Aquifer by the U Plant Area P&T System

Constituent	Mass (Activity) Removed during 2016	Mass (Activity) Removed since Startup
Carbon tetrachloride, kg	24.4	29.7
Nitrate (as NO_3), kg	48,800	71,100
Technetium-99, g (Ci)	27.5 (0.47)	38.5 (0.66)
Uranium, kg	9.9	11.7

3.3.1.3 Treatment System Mass Removal

As discussed, extracted groundwater is conveyed to the 200 West P&T and passes through IX resin for radiological treatment. The effluent from the resin is then combined with the influent groundwater from other extraction wells (that do not require radiological treatment) and is passed through the central treatment process. The effluent from the treatment system is then returned to the aquifer using injection wells. Chapter 2, Section 2.1 provides a description of the treatment system and its performance during 2016. The uranium and technetium-99 removal efficiencies for the entire system during 2016 averaged 98 and 96%, respectively, and the nitrate removal efficiency averaged 81% (Chapter 2, Section 2.1, Table 2-1). Average concentrations in the effluent from the treatment system met all the cleanup levels specified in the 200-UP-1 ROD (EPA et al., 2012; Chapter 2, Section 2.2.4, Table 2-6).

3.3.2 Water Level Monitoring

Water level monitoring is performed to evaluate the effect of the U Plant P&T system on the water table and to evaluate the effectiveness of the system in capturing the contaminant plumes. The following subsections describe the data interpretation for 2016.

3.3.2.1 Water Level Measurements

During 2016, synoptic manual depth-to-water measurements were collected monthly throughout the year. In accordance with DOE/RL-2015-14, monthly manual measurements will be collected for 1 year, then an evaluation will be made to determine if the measurement frequency can be reduced (e.g., to quarterly). Some wells are equipped with pressure transducers and data loggers for automated water level measurements (Figure 3-2). When reviewing and interpreting water level data, the flow rates recorded at each extraction well are also reviewed to provide an understanding of the probable causes of changes in groundwater levels.

3.3.2.2 Hydraulic Capture Analysis

Groundwater levels and pumping rates were used to map the water table in the U Plant area and estimate the hydraulic capture zone of the P&T system. The March 2015 water table map for the U Plant area constructed by universal kriging is provided in Figure 3-29. This map depicts the water table conditions prior to startup of the U Plant area P&T system in September 2015. Groundwater flow within this area is toward the northeast due to drawdown of the water table by the 200-ZP-1 P&T system.

Figure 3-30 depicts the water table estimated capture zone for December 2016, as well as the uranium plume in groundwater. The capture zone was estimated by mapping the groundwater elevation data for December using MEUK and tracking particles on the mapped surface for a duration of 22 years (i.e., until 2037). Particle tracking was performed by releasing particles in a circle, enveloping each extraction well, and tracking them backward. This results in an “instantaneous” depiction of the extent of capture under December 2016 conditions (i.e., the groundwater flow lines depict the approximate area of the aquifer that would be captured by the extraction wells over a 22-year period if the water table configuration during December 2016 represented steady-state conditions). The calculated groundwater flow lines indicate the focus area of hydraulic containment and mass recovery for the U Plant area extraction wells under current conditions.

Figure 3-30 indicates that the system is focused on capturing the central portion of the uranium plume, as designed. The system is expected to capture about 60% of the areal extent of the uranium plume above 30 µg/L and about 70% of the plume above 300 µg/L. One well, 299-W19-115, is near the source area, and another, 299-W19-116, was installed at the distal end of the plume (Figure 3-28). Two additional wells, 299-W19-123 and 299-W19-125, will be installed in 2017 with well 299-W19-125 planned as an extraction well, southwest and northeast of the 300 µg/L plume, respectively. As data from operations and new monitoring wells become available, numerical modeling for system optimization will be performed to evaluate system performance and ensure that remediation objectives will be achieved. If performance monitoring data and/or the modeling indicate that remediation objectives will not be achieved with the current system, then alternatives to improve capture will be investigated.

Figures 3-31 and 3-32 show the December 2016 capture zones with the technetium-99 and nitrate plumes, respectively. The technetium-99 plume is well covered by the capture zones, and only a small portion of the western end of the interpreted plume is not within a capture zone. For nitrate, all concentrations in the U Plant area are now below the high-concentration level (i.e., greater than 450 mg/L). The selected remedies for nitrate were P&T for the high-concentration area at U Plant and MNA for the remainder of the plume.

The capture zones for 299-W19-113 and 299-W19-114 were determined by mapping of water level measurements, along with the capture zones predicted by model simulations when the system was designed, are depicted in Figure 3-33. There is very good agreement between the mapped and predicted capture zones.

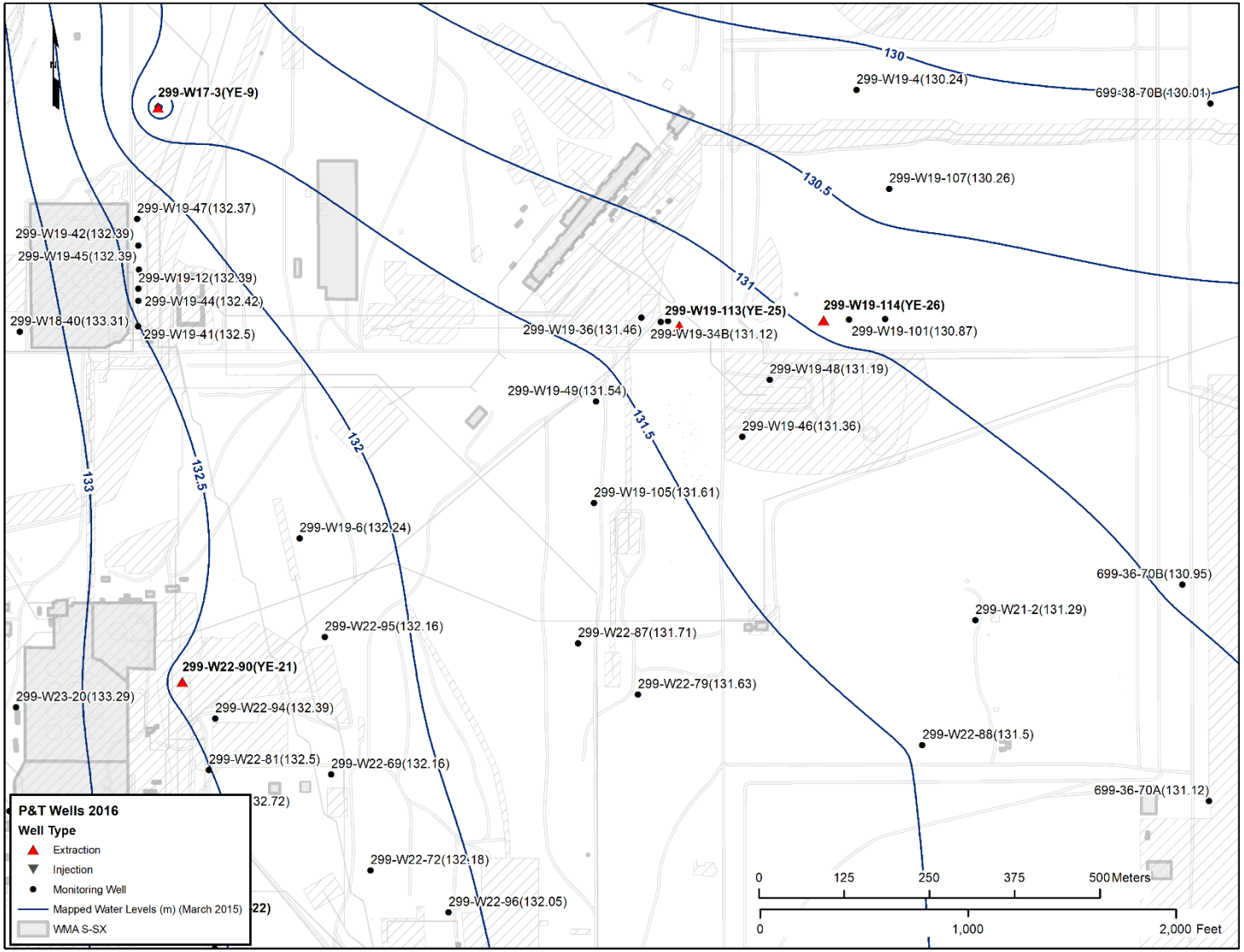


Figure 3-29. Baseline Water Table for the U Plant Area, March 2015

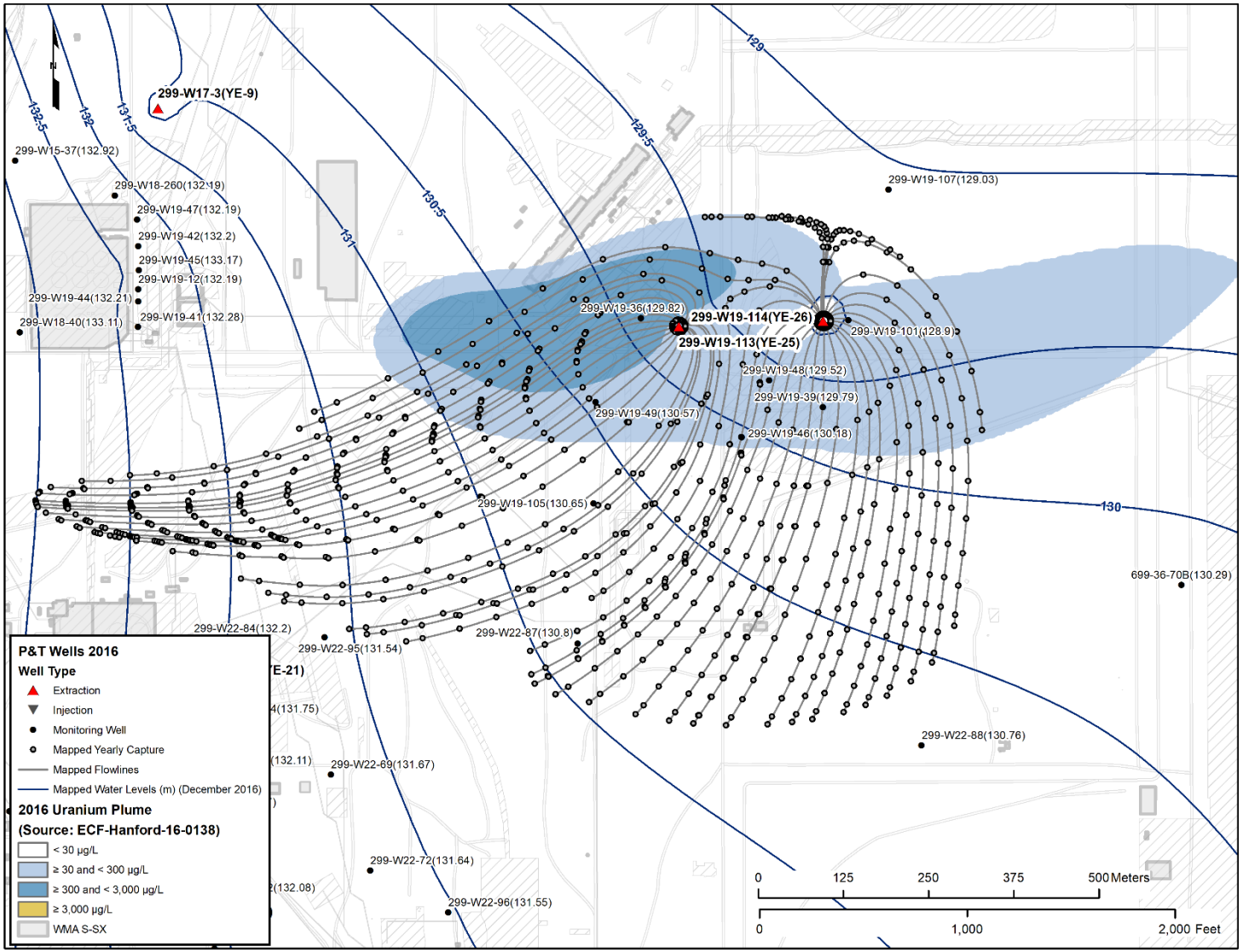


Figure 3-30. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area P&T System under December 2016 Conditions (Steady-State Assumption) Compared to the Uranium Plume

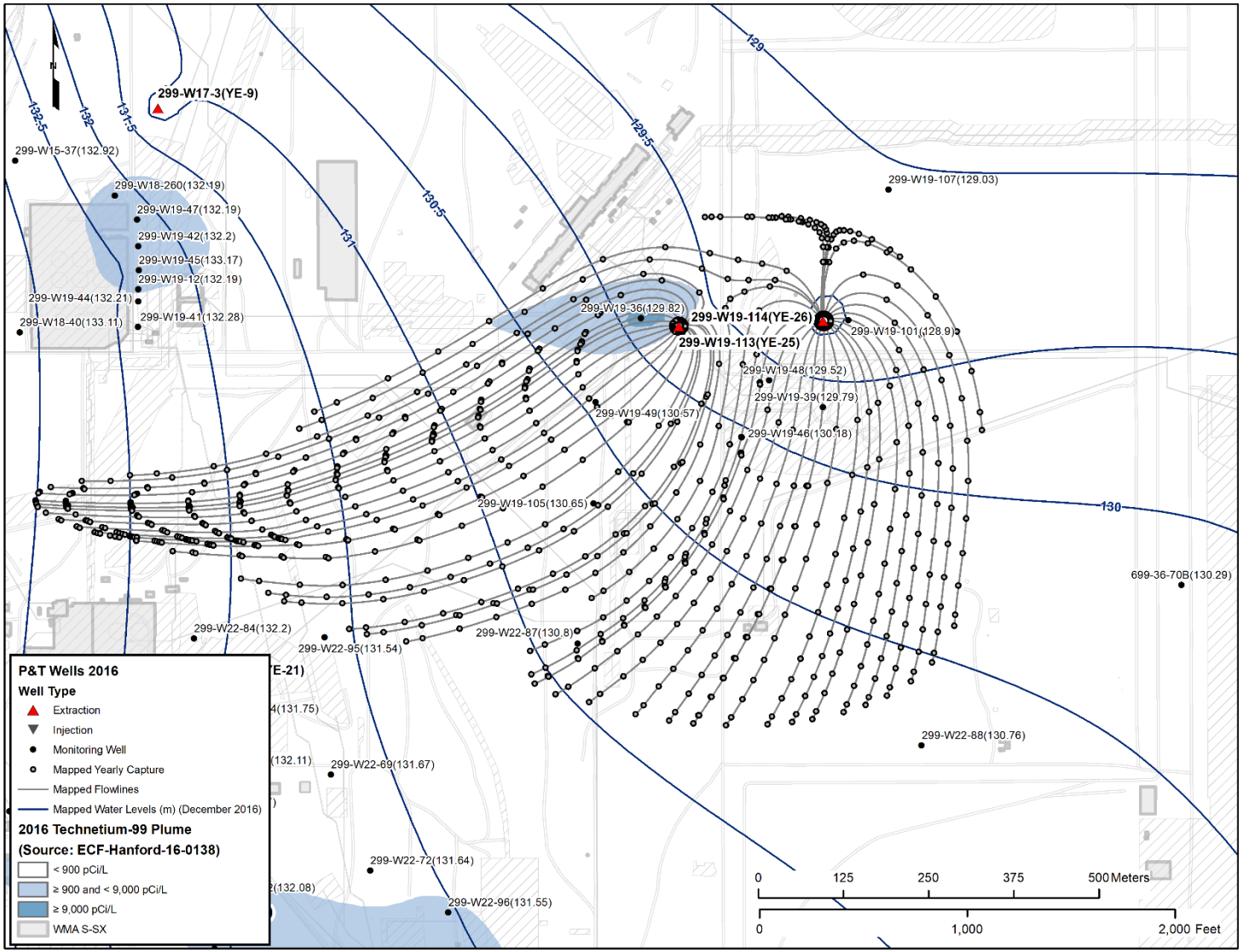


Figure 3-31. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area P&T System under December 2016 Conditions (Steady-State Assumption) Compared to the Technetium-99 Plume

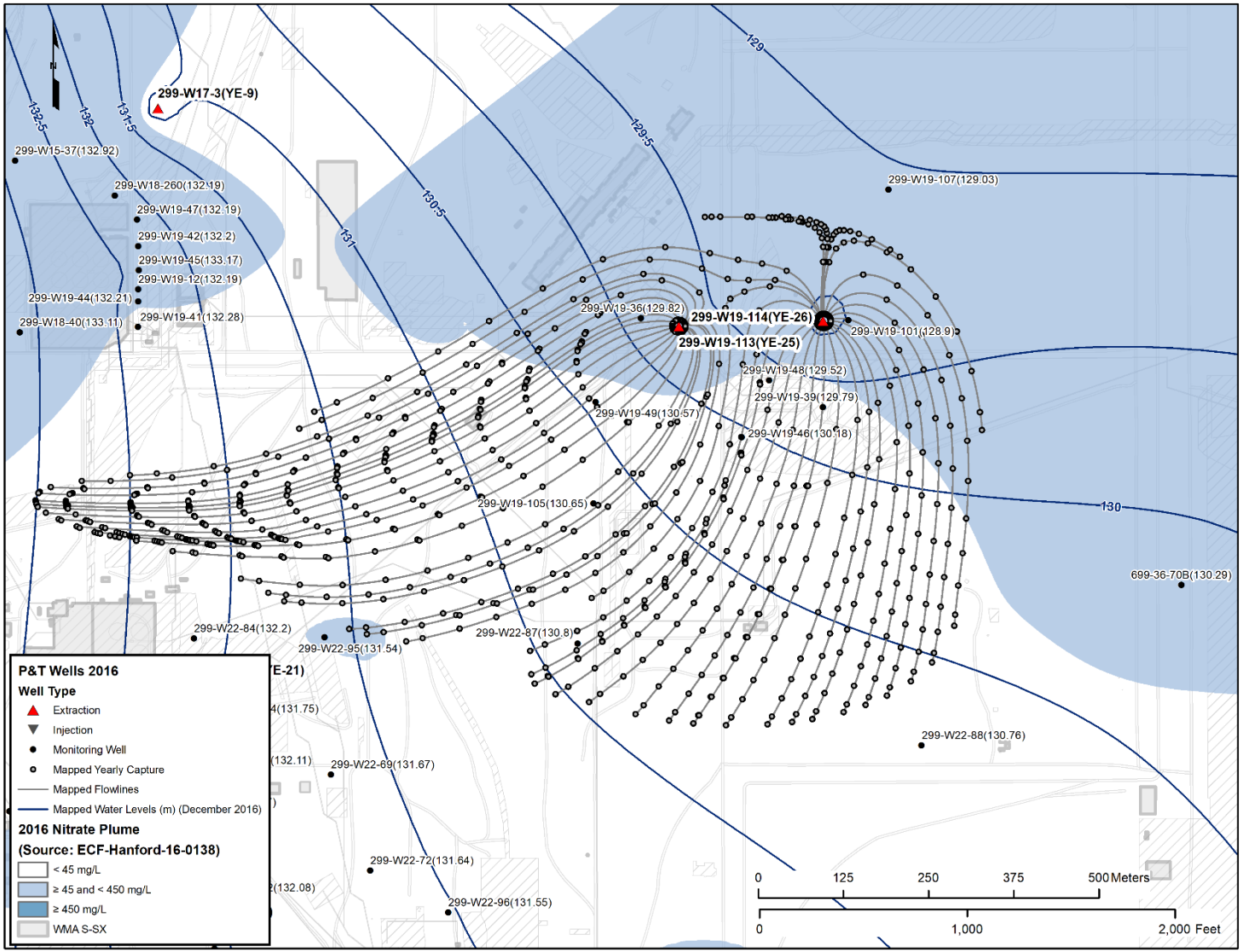


Figure 3-32. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area P&T System under December 2016 Conditions (Steady-State Assumption) Compared to the Nitrate Plume

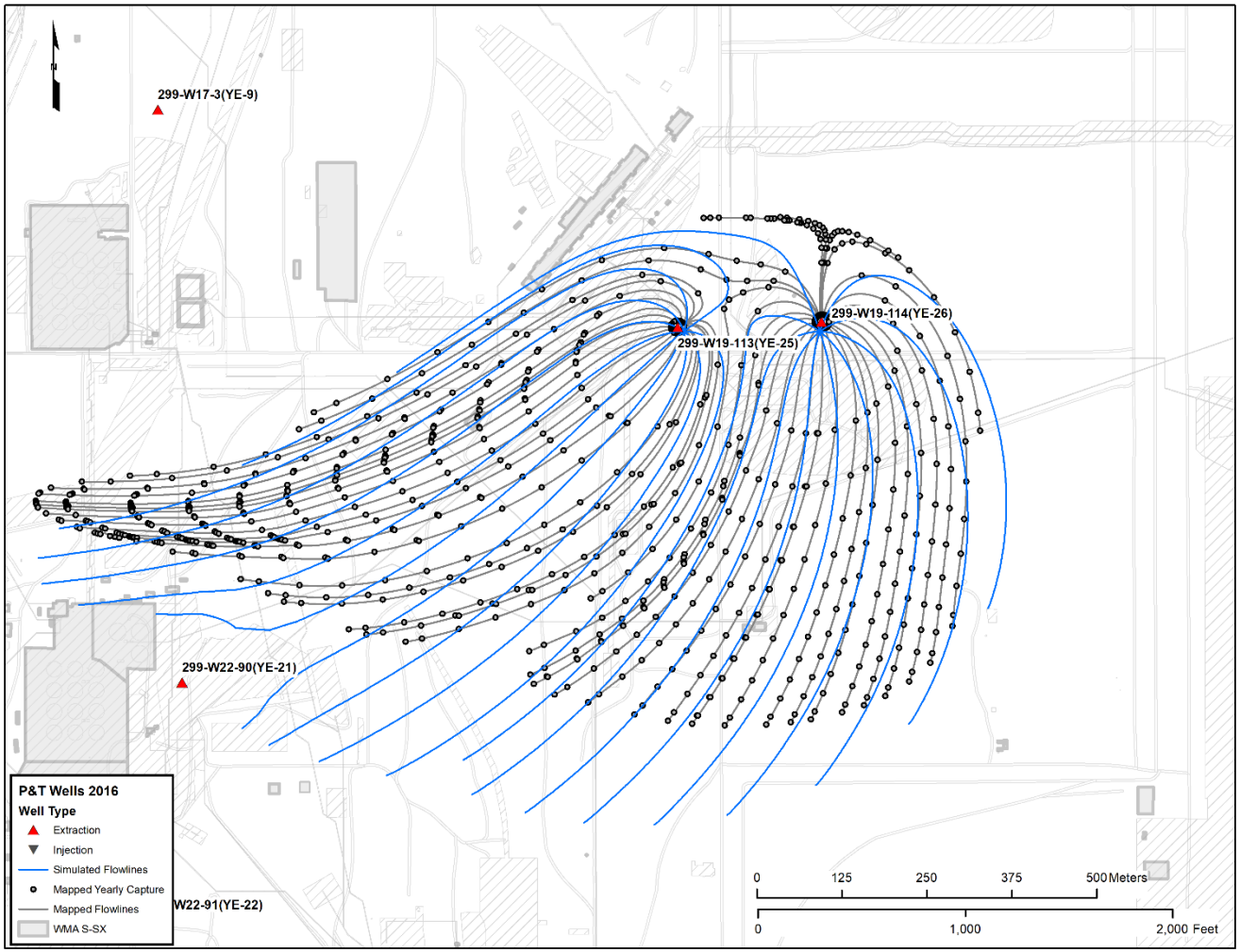


Figure 3-33. Comparison of Mapped Hydraulic Capture for the U Plant Area P&T System using Water Level Measurements from December 2016 (Steady-State Assumption) Compared to the Design Capture Zone Determined by Groundwater Modeling

3.3.3 Contaminant Monitoring

This section summarizes the 2016 results for groundwater sampling near the U Plant Area groundwater extraction system. A comprehensive discussion of groundwater contamination within the OU is provided in the RI/FS (DOE/RL-2009-122). The vertical distribution of the plumes is shown as cross-sectional maps in the RD/RAWP (DOE/RL-2013-07). Discussions of recent monitoring results for the entire OU are provided in Chapter 11 of DOE/RL-2016-67.

Groundwater contamination baseline conditions from which cleanup progress is evaluated were established during 2015 (Section 2.3.3 of 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*). In the following subsections, sample results for uranium, technetium 99, nitrate, and carbon tetrachloride during 2016 are presented and compared to baseline concentrations. When more than one sample result was available in a well, the last sample collected during 2016 was used in the comparisons to represent cleanup progress achieved during the year. Depictions of plumes are based on annual average concentrations in the wells and are the same as those presented in DOE/RL-2016-67.

The 2016 uranium, technetium-99, nitrate, and carbon tetrachloride sample results from the monitoring wells in the U Plant Area vicinity are compared to baseline concentrations (i.e., concentrations in the aquifer determined during 2015 prior to operation of the groundwater extraction system) in Tables 3-10, 3-11, 3-12, and 3-13, respectively. These comparisons are also shown in Figures 3-34 and 3-35, Figures 3-36 and 3-37, Figures 3-38 and 3-39, and Figures 3-40 and 3-41, respectively. Figures 3-34, 3-36, 3-38, and 3-40 show bar charts of the 2016 concentrations compared to the baseline 2015 concentrations. Figures 3-35, 3-37, 3-39, and 3-41 show location of the monitoring wells in relation to the U Plant extraction wells along with pie chart depictions of the 2016 to 2015 concentration comparison for the monitoring wells.

3.3.3.1 Uranium Monitoring Results

The uranium plume from the 216-U-1 and 216-U-2 Cribs extends 1.5 km (0.9 mi) to the east from the cribs at levels above the 30 µg/L cleanup level (Figure 3-28). Monitoring wells are used in assessing plume concentrations. Extraction well sample results are subject to being affected by concentration averaging from surrounding water also being drawn into the extraction wells. Within this plume, two replacement monitoring wells were drilled during 2016 (299-W19-115 replaced dry well 299-W19-18 and 299-W19-116 replaced dry well 699-38-70). Additional information regarding well construction information is available online (Environmental Dashboard Application, 2017). With the exception of 299-W19-36 and 299-W19-101, uranium concentration trends within the plume have been declining (Table 3-10). The concentration at 299-W19-36 increased by 55% from its baseline of 1,550 µg/L in July 2015 to 2,400 µg/L in August 2016 (Figure 3-42). The concentration at 299-W19-101 increased by 28% from its baseline of 78 µg/L in August 2015 to 100 µg/L in August 2016. The increase in 299-W19-101 indicates that water with high uranium concentration is being drawn toward the wells by the nearby extraction wells 299-W19-113 and 299-W19-114. Concentrations at 299-W19-36 began to increase before groundwater extraction began. There may be a local source in the vicinity of 299-W19-36 (Figure 3-28). The second highest concentrations occur at 299-W19-115, a replacement well for 299-W19-18, located about 100 m (328 ft) downgradient from the cribs. The latest uranium sample result from this well was 380 µg/L in October 2016, a 48% decrease from the 734 µg/L baseline result in 2015 (Figure 3-42). Concentrations at well 299-W19-43 (Figure 3-43) have decreased 40% from the baseline, and the concentration have been generally stable at 299-W19-49 in 2016 (Figure 3-42).

Table 3-10. Comparison of 2016 Uranium Sample Results from Monitoring Wells in the U Plant Area P&T Vicinity to Baseline Concentrations

Well Name	Baseline (2015) Uranium (µg/L)	2016 Uranium (µg/L) [a]	Difference (%) [b]
299-W19-36	1,550	2,400	+55
299-W19-115 [c]	734 [c]	380	-48
299-W19-43	223	133	-40
299-W19-49	223	147	-34
299-W19-48	102	41	-60
299-W19-101	78	100	+28
299-W19-39	65	44.6	-31
299-W19-46	63.3	37	-42
299-W19-105	25.7	23.6	-8
299-W19-116 [d]	10 [d]	Not applicable [d]	—
299-W19-34A	1.44	1.25	-13
299-W19-107	1.35	1.4	+4

a. For wells that were sampled multiple times during 2016, the result shown is from the last sample of the year.

b. Differences shown are for only those wells with a baseline or 2016 sample result at least five times the detection limit (1 µg/L × 5 = 5 µg/L; i.e., results above an approximation of the quantitation limit).

c. Baseline sample result is for 299-W19-18, which is dry. The replacement well is 299-W19-115.

d. Baseline sample result was from March 2016 sampling results, and no comparison is made.

Table 3-11. Comparison of 2016 Technetium-99 Sample Results from Monitoring Wells in the U Plant Area P&T Vicinity to Baseline Concentrations

Well Name	Baseline (2015) Technetium-99 (pCi/L)	2016 Technetium-99 (pCi/L) [a]	Difference (%) [b]
299-W19-36	51,400	13,900	-73
299-W19-43	8,080	164	-98
299-W19-115 [c]	580 [c]	701	+21
299-W19-34A	486	947	+96
299-W19-116	450 [d]	Not applicable [d]	—
299-W19-49	304	148	-51
299-W19-107	273	123	-55
299-W19-101	234	346	+48
299-W19-48	139	189	+36

a. For wells that were sampled multiple times during 2016, the result shown is from the last sample of the year.

b. Differences are shown for only those wells with a baseline or 2016 sample result at least five times the detection limit (~6.6 pCi/L × 5 = ~33 pCi/L).

c. Baseline sample result is for 299-W19-18, which is dry. The replacement well is 299-W19-115.

d. Baseline sample result was from March 2016 sampling results, and no comparison is made.

Table 3-12. Comparison of 2016 Nitrate Sample Results from Monitoring Wells in the U Plant Area P&T Vicinity to Baseline Concentrations

Well Name	Baseline (2015) Nitrate (mg/L)	2016 Nitrate (mg/L) [a]	Difference (%)
299-W19-43	3,190	133	-96
299-W19-36	788	208	-74
299-W19-4	165	Not sampled	—
299-W19-116 [b]	115[b]	Not applicable [b]	—
299-W19-107	112	48.7	-57
299-W19-39	66.4	33.6	-49
299-W19-115 [c]	58.4[c]	44.3	-24
299-W19-48	57.5	27.4	-52
299-W19-49	38.6	19.9	-48
299-W19-34A	34	53.1	+56
299-W19-46	29.9	18.6	-38
299-W19-101	29.7	93	+213

a. For wells that were sampled multiple times during 2016, the result shown is from the last sample of the year.

b. Baseline sample result was from March 2016 sampling results, and no comparison is made.

c. Baseline sample result is for 299-W19-18, which is dry. The replacement well is 299-W19-115.

Table 3-13. Comparison of 2016 Carbon Tetrachloride Sample Results from Monitoring Wells in the U Plant Area P&T Vicinity to Baseline Concentrations

Well Name	Baseline (2015) Carbon Tetrachloride (µg/L)	2016 Carbon Tetrachloride (µg/L) [a]	Difference (%) [b]
299-W19-49	136	305	+124
299-W19-34B	135	106	-22
299-W19-34A	91.6	91.3	-0.3
299-W19-107	82	150	+82.9
299-W19-48	35	22	-37
299-W19-105	27.3	40	+47
299-W19-116 [c]	17 [c]	Not applicable [c]	—
299-W19-115 [d]	10 [d]	220	+2,100
299-W19-36	9.9	13	+31

a. For wells that were sampled multiple times during 2016, the result shown is from the last sample of the year.

b. Differences shown are for only those wells with a baseline or 2016 sample result at least five times the detection limit (1 µg/L × 5 = 5 µg/L; i.e., results above an approximation of the quantitation limit).

c. Baseline sample result was from March 2016 sampling results, and no comparison is made.

d. Baseline sample result is for 299-W19-18, which is dry. The replacement well is 299-W19-115.

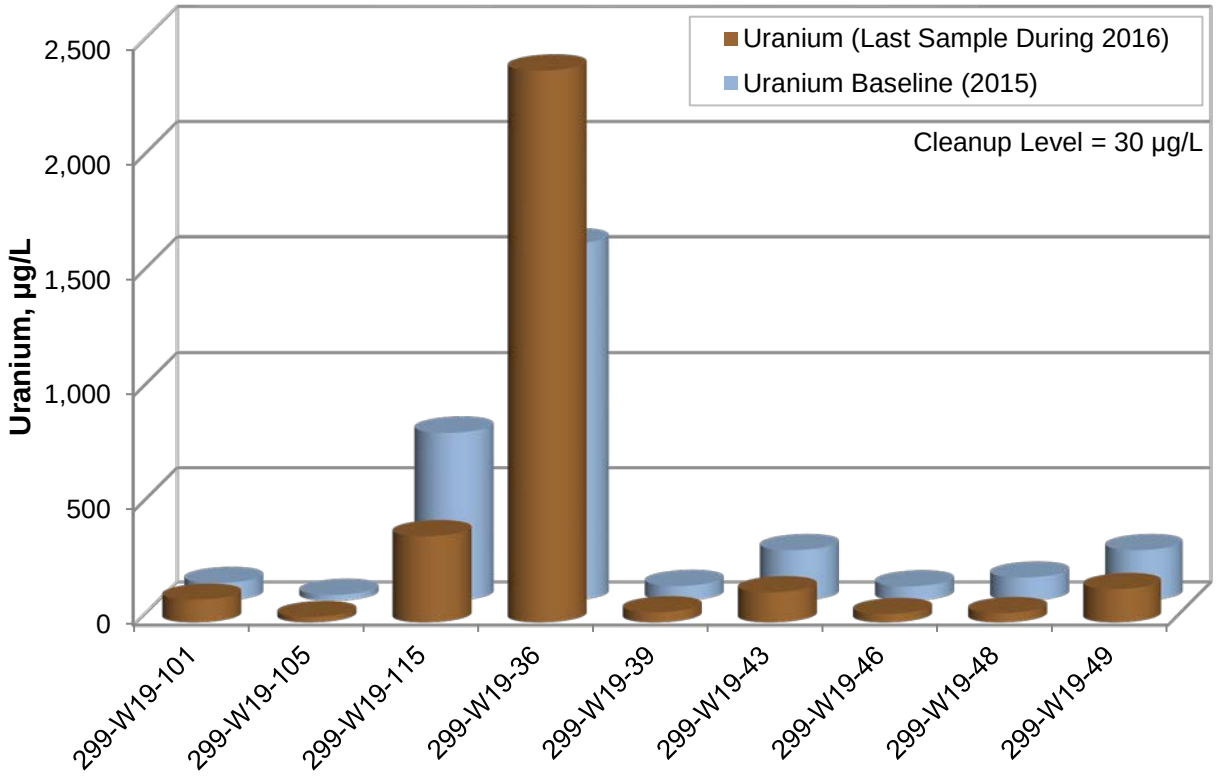


Figure 3-34. Comparison Chart of 2016 Uranium Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

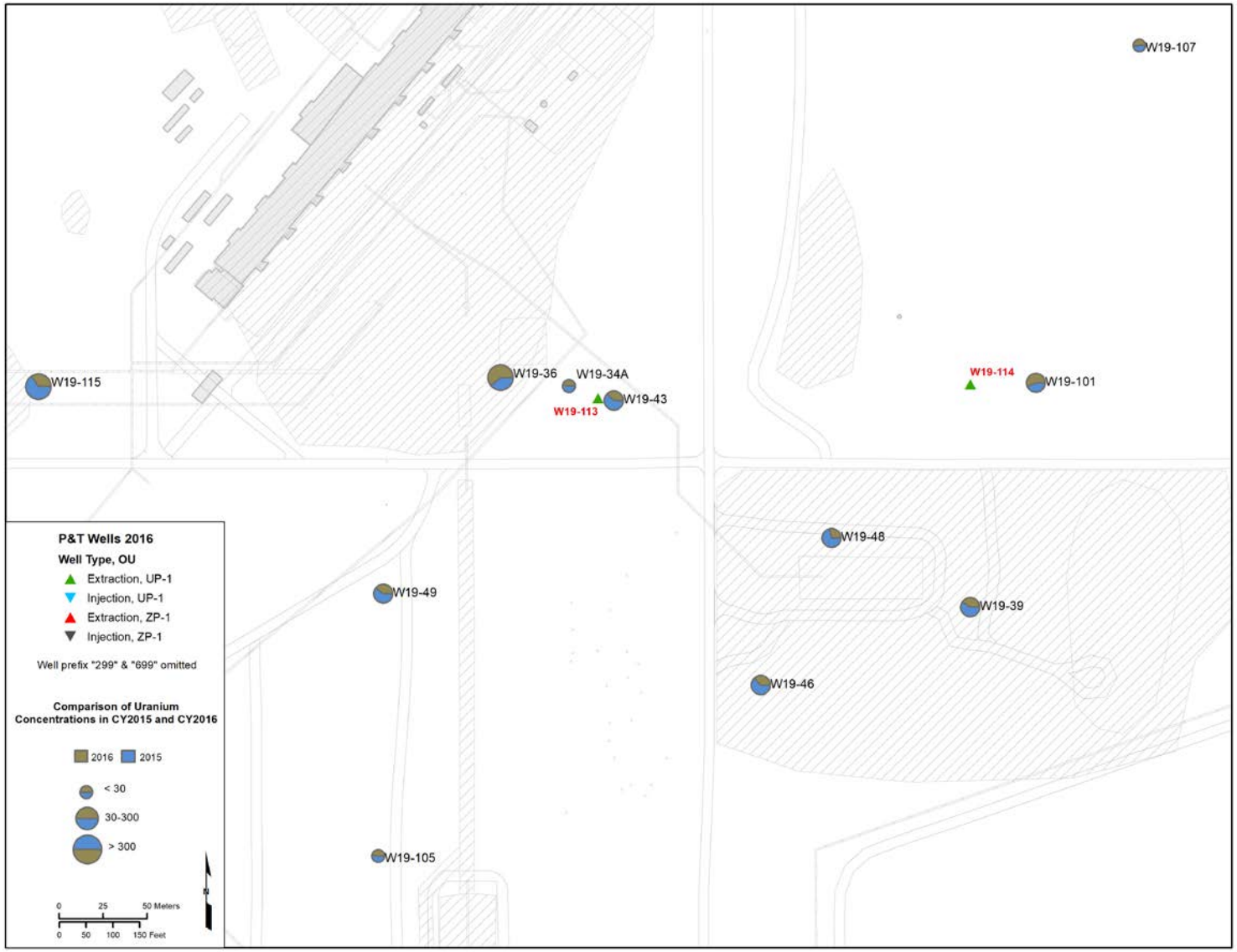


Figure 3-35. Comparison Map of 2016 Uranium Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

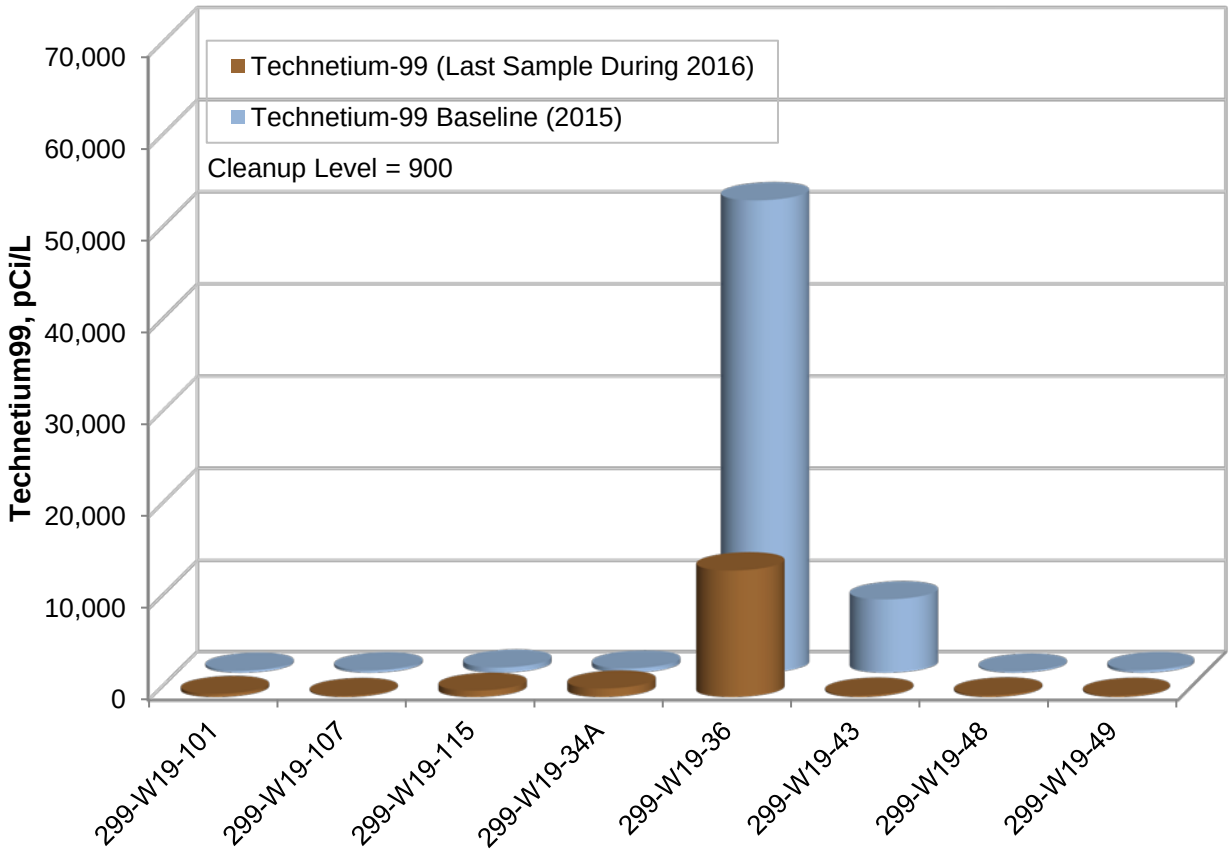


Figure 3-36. Comparison Chart of 2016 Technetium-99 Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

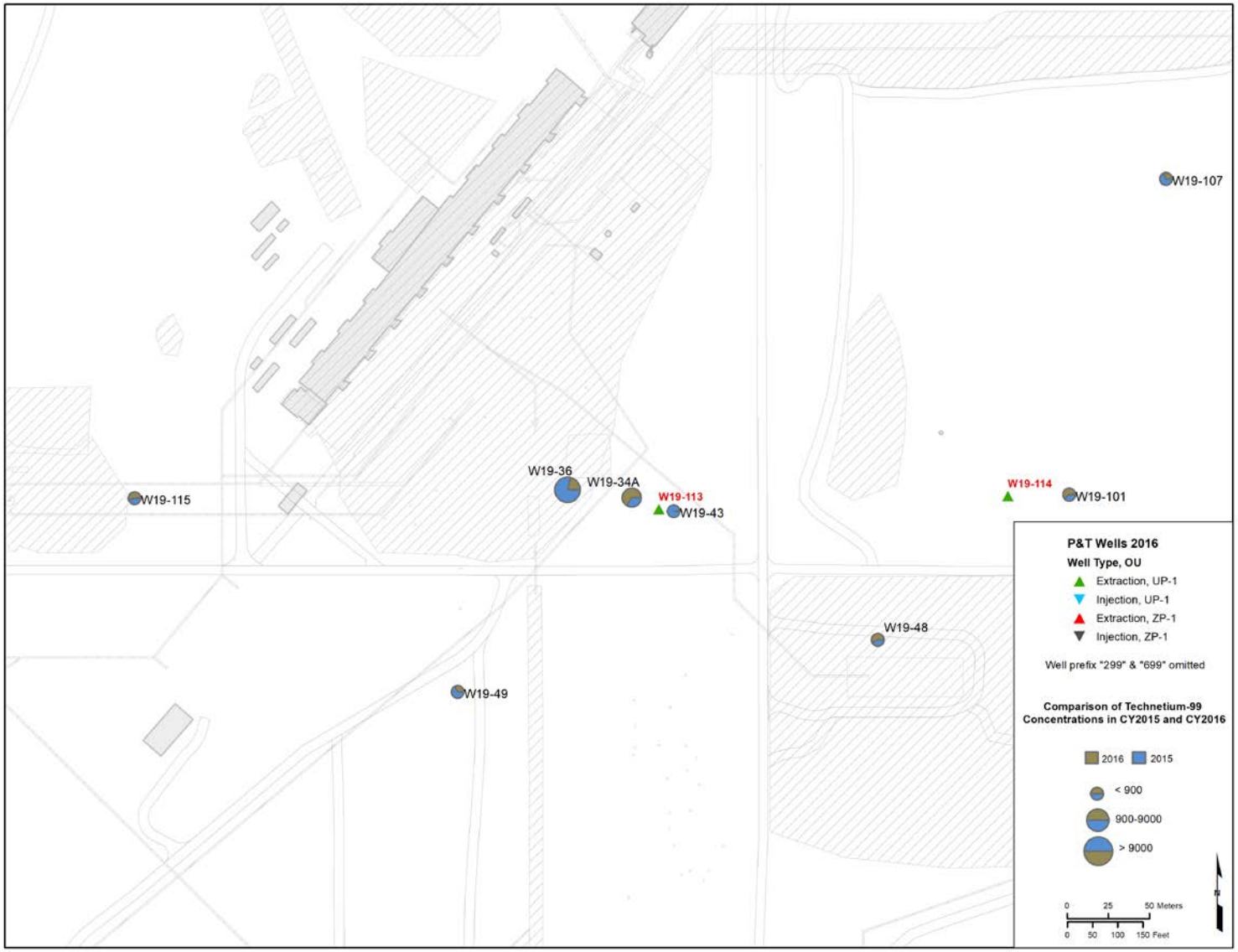


Figure 3-37. Comparison Map of 2016 Technetium-99 Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

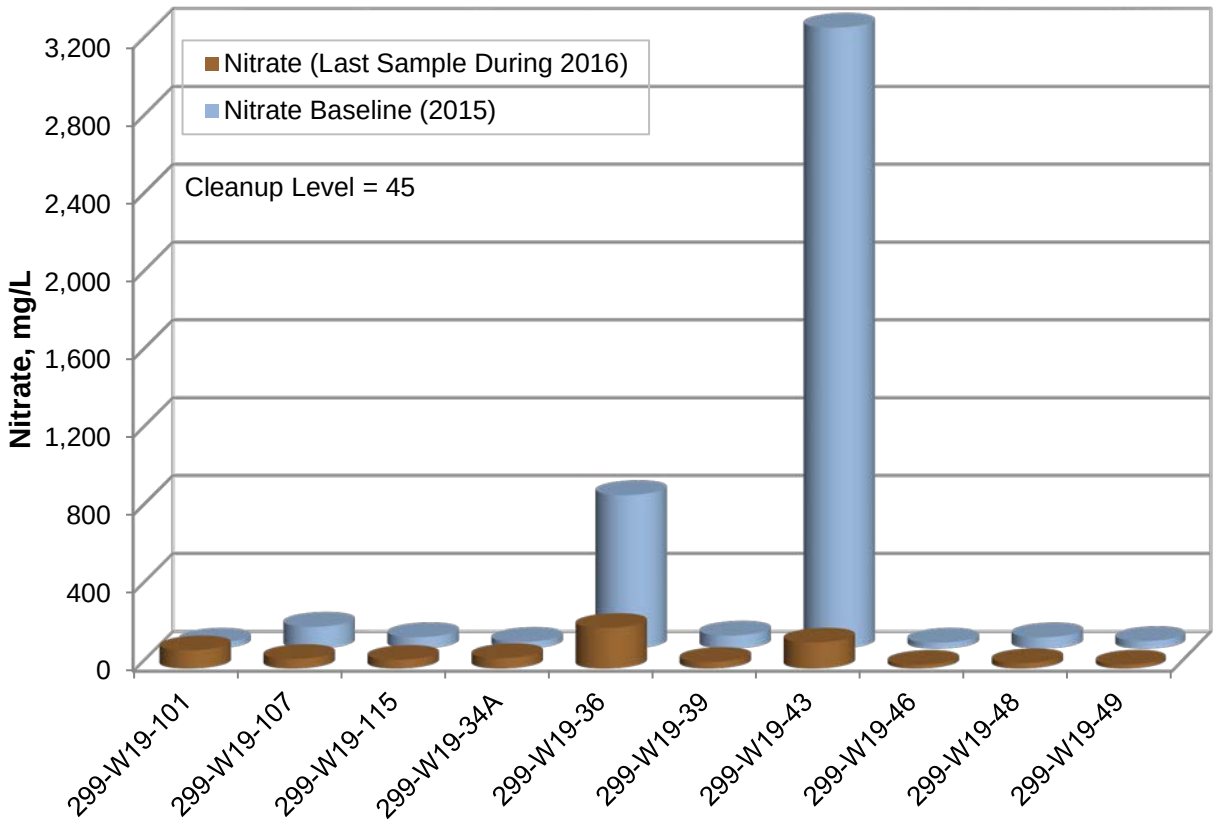


Figure 3-38. Comparison Chart of 2016 Nitrate Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

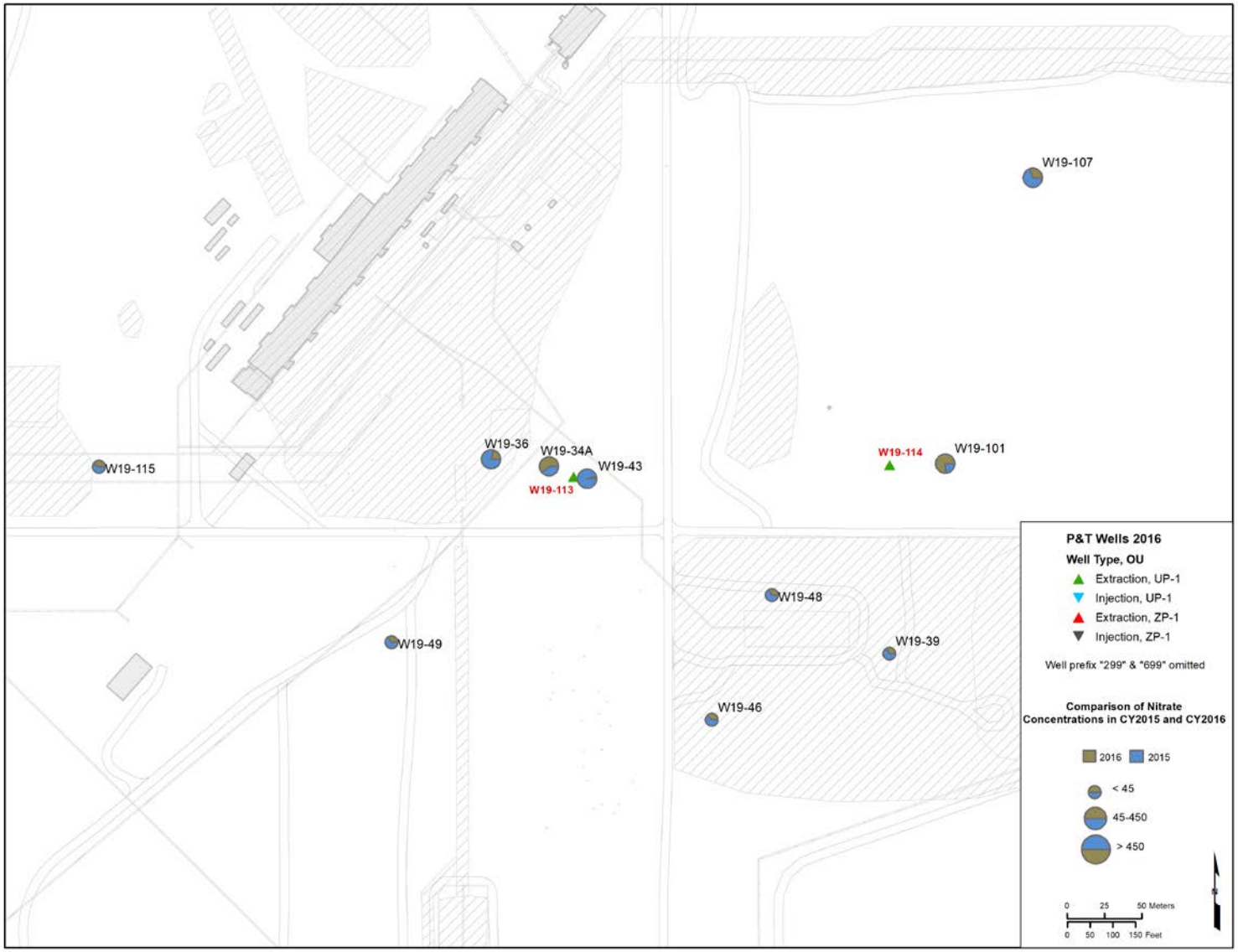


Figure 3-39. Comparison Map of 2016 Nitrate Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

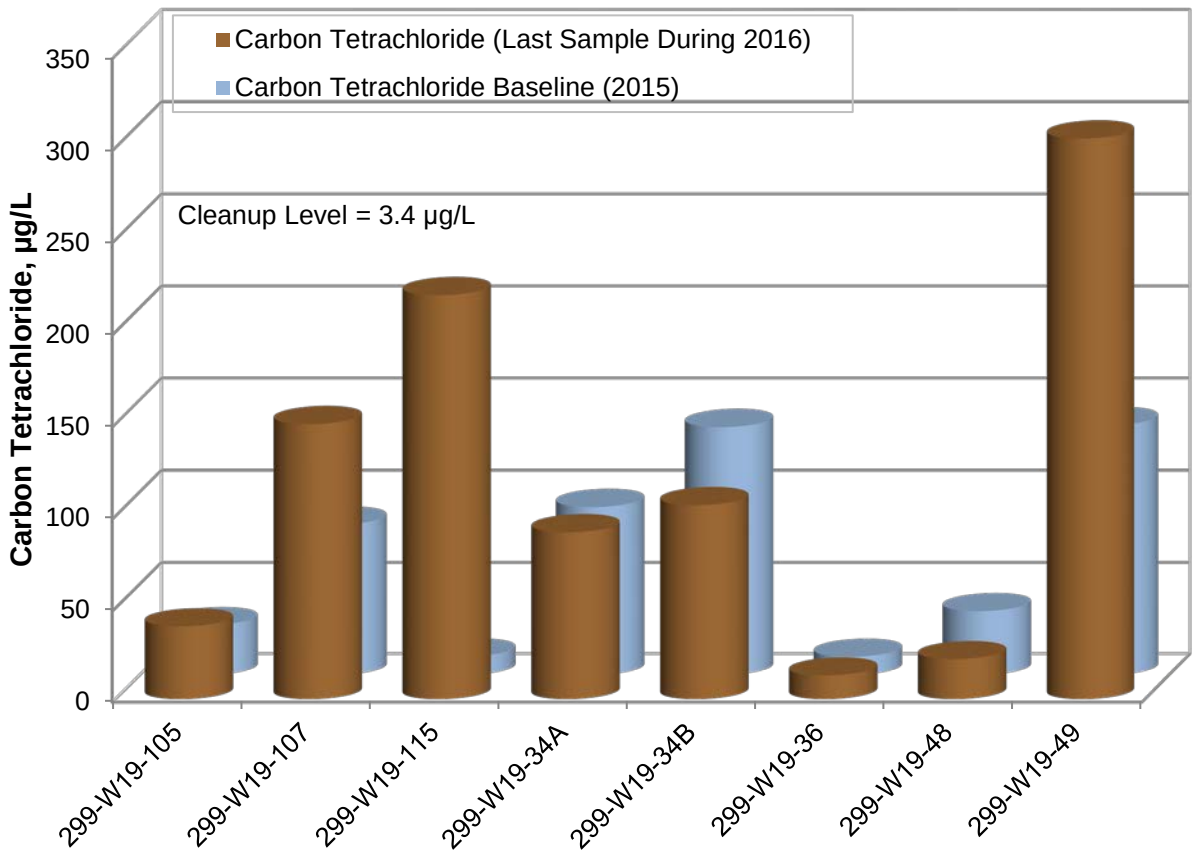


Figure 3-40. Comparison Chart of 2016 Carbon Tetrachloride Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

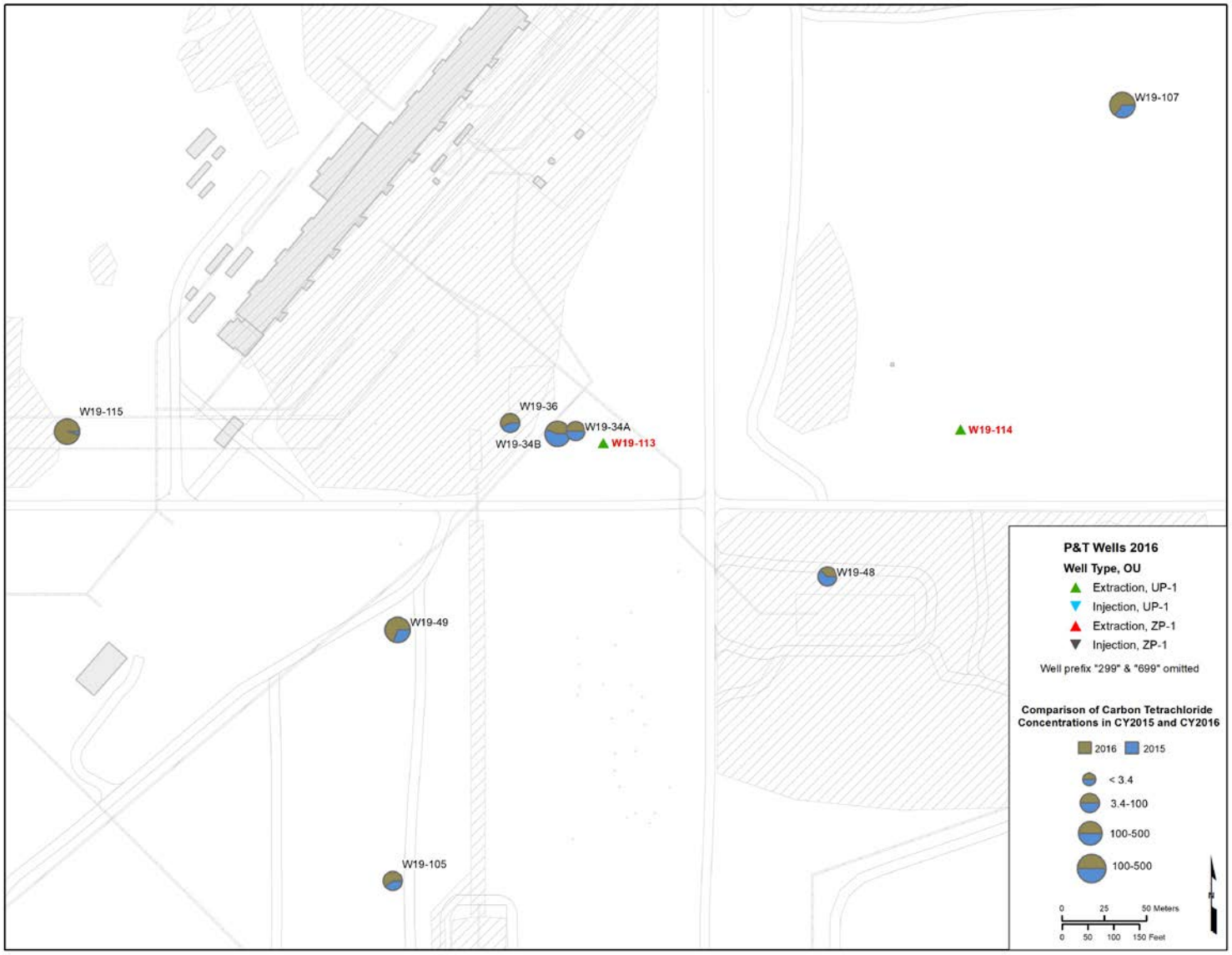


Figure 3-41. Comparison Map of 2016 Carbon Tetrachloride Sample Results for Selected Monitoring Wells near the U Plant Area P&T to Baseline Concentrations Prior to the Start of Groundwater Extraction

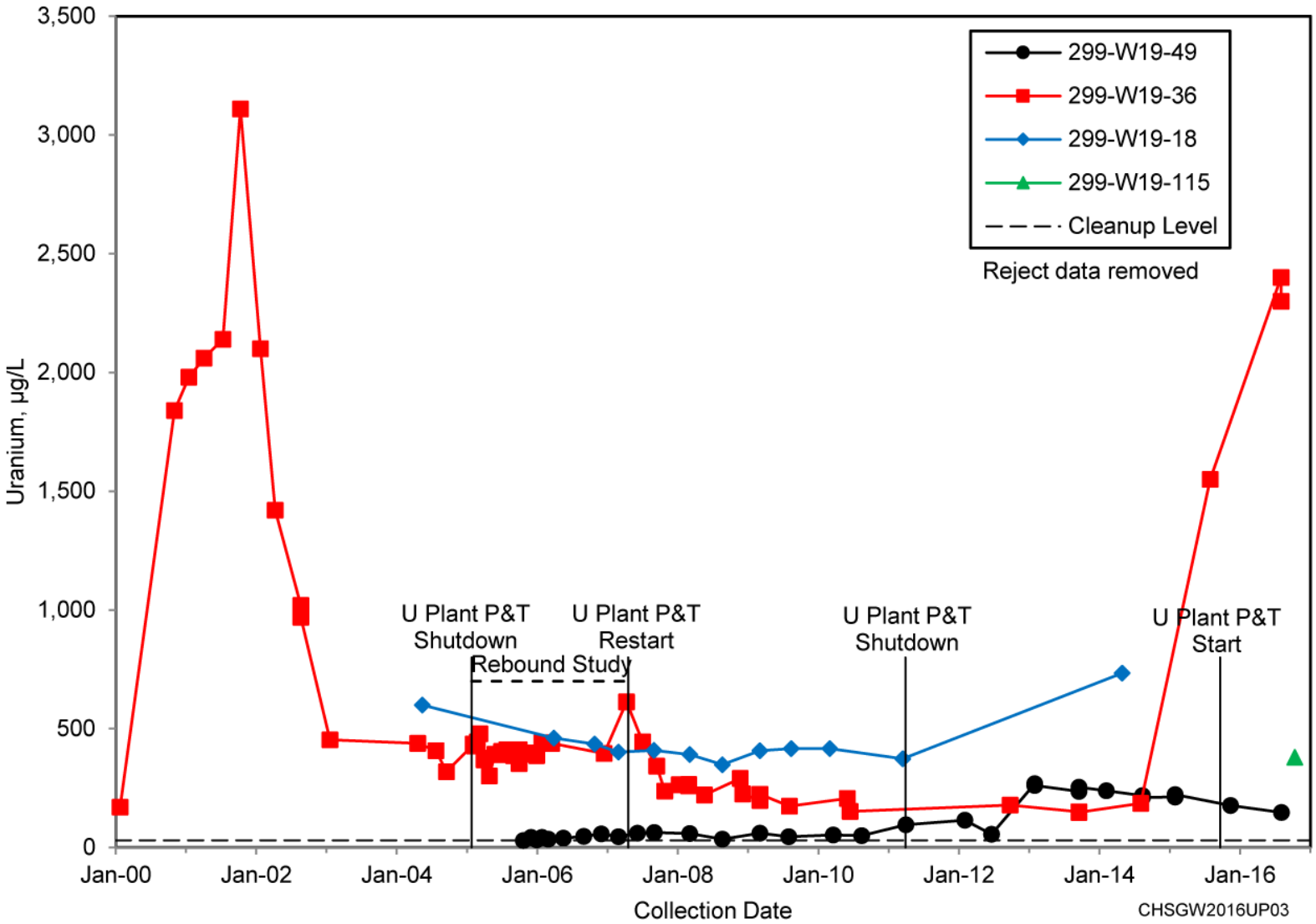


Figure 3-42. Uranium Concentrations in Selected Wells Downgradient from the 216-U-1 and 216-U-2 Cribs

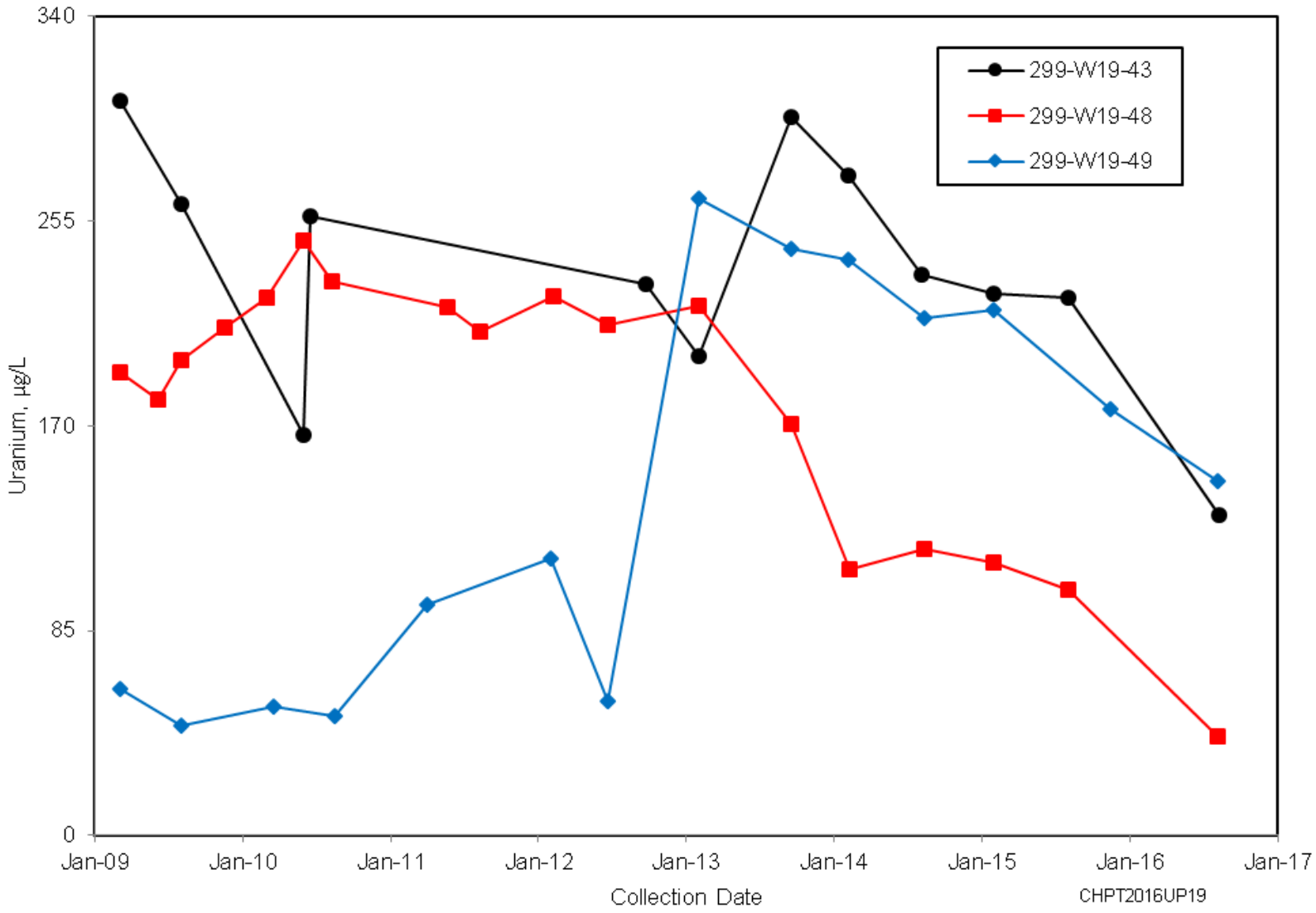


Figure 3-43. Uranium Concentrations in Selected Wells at the U Plant Area P&T System, 2016

Depth-discrete sampling during drilling indicates that the uranium plume occurs within the upper 21 m (69 ft) of the aquifer. Results of sampling during drilling of the monitoring wells (299-W19-115, 299-W19-116, and dual-use monitoring/extraction wells 299-W19-123 and 299-W19-125) are shown in Table 3-14 (well locations in Figure 3-28). Uranium was found in the four uppermost samples from 299-W19-115 at 200, 210, 52 and 75 µg/L (4.3 to 21.8 m [14.2 to 71.5 ft] below the water table) but was 2.1 µg/L at 27.7 m (90.8 ft) below the water table, which is within the Hanford Site background range (95th percentile of 14.4 µg/L [DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*]). At 299-W19-116, the highest uranium result during drilling was 37 µg/L in the uppermost sample, but falls to below the Hanford Site background range at 12 m (39.3 ft) below the water table with 8.1 µg/L. At 299-W19-123 and 299-W19-125, well drilling and construction will be completed in 2017, but early drilling results show the highest uranium concentrations were 14 and 5.2 µg/L, respectively, though these results may not be representative of the aquifer. The drilling process can cause temporary reducing conditions, particularly when the cable tool method is used. Some constituents that are soluble under oxidizing conditions will become insoluble under reducing conditions, which may be the case with uranium. Wells 299-W19-115, 299-W19-123, and 299-W19-125 were drilled by the cable tool method, whereas 299-W19-116 was drilled by air rotary, which does not induce reducing conditions to the same degree. This may explain why the uranium concentrations were low at 299-W19-123 and 299-W19-125 even though these wells were installed near the center of the uranium plume.

Table 3-14. Depth Profile Sample Results for the U Plant Area Uranium Plume Monitoring Wells

Well Name	Depth (ft) below Water Table	Carbon Tetrachloride (µg/L)	Nitrate (mg/L as NO_3)	Technetium-99 (pCi/L)	Uranium (µg/L)
299-W19-115	14.2	240	19.9	332	200 [a]
	33.9	390	21.3	258	210 [a]
	51.6	200	10.6	172	52 [a]
	71.5	150	9.7	93.5	75 [a]
	90.8	120	5.8	99.7	2.1 [a]
299-W19-116	9.1	13	97.4	387	37
	39.3	19	115	446	8.1
	69.9	8.1	102	300	2.4
	98.8	8.9	102	240	1.7
	119	21	66.4	189	1.2
	148.6	19	57.5	144	1.3
	164.7	18	57.5	148	1.2
299-W19-123 [b]	12.1	200	18.6	261	14 [a]
	36.4	230	15.9	219	1.4 [a]
	67.5	240	12.8	124	1.4 [a]
299-W19-125 [b]	13.9	390	88.6	203	2.7 [a]
	29.7	260	97.4	291	5.2 [a]
	60.3	69	NA	172	1.1 [a]
	89.5	97	15.9	65.9	1 [a]

a. Results may have been affected (i.e., biased low) by temporary reducing conditions caused by cable tool drilling method.

b. Well drilling and construction to be completed in 2017.

3.3.3.2 Technetium-99 and Nitrate Monitoring Results

The technetium-99 and nitrate plumes in the U Plant area are shown in Figures 3-44 and 3-45, respectively. Technetium-99 concentrations exceed the 900 pCi/L cleanup level only in a former extraction well of the interim action system, 299-W19-36, and nearby well 299-W19-113 which is one of the two extraction wells for the new P&T system (Figures 3-44 and 3-46). The baseline concentration in 299-W19-36 was 51,400 pCi/L (Table 3-11). The concentration increased from 21,000 pCi/L in September 2013 to 86,500 pCi/L in August 2014 but subsequently declined to 13,900 pCi/L in August 2016. Baseline concentrations in the new extraction wells during October 2015 shortly after startup of groundwater extraction were 8,610 pCi/L in 299-W19-113 and 980 pCi/L in 299-W19-114. The concentration in 299-W19-114 was below the cleanup level throughout 2016.

The highest baseline nitrate concentrations in the U Plant Area occur at the former extraction wells: 299-W19-36 and 299-W19-43 (Figures 3-45 and 3-47). Baseline concentrations in these wells were 788 and 3,190 mg/L, respectively. Concentrations have declined in six of the eight wells with a baseline nitrate concentration above the 45 mg/L cleanup level (Table 3-12). For the six wells with declining nitrate concentrations that had a baseline concentration above the cleanup level, all but two (299-W19-39 and 299-W19-115 at 49% and 24%, respectively) of the declines are greater than 50% (ranging from 52% to 96%). Concentrations have declined to below the nitrate cleanup level in three wells (299-W19-39, 299-W19-115, and 299-W19-48). Concentrations have increased above the nitrate cleanup level in 299-W19-34A and 299-W19-101 (56% and 213% over baseline, respectively). The concentration increase in 299-W19-34A indicates that water with high nitrate concentration is being drawn into the nearby upgradient extraction well 299-W19-113. The increase in 299-W19-101 indicates migration of the nitrate plume toward the extraction well 299-W19-114.

3.3.3.3 Carbon Tetrachloride Monitoring Results

Cleanup of carbon tetrachloride is not an objective of the U Plant remedy, but the extraction wells do remove carbon tetrachloride from the aquifer and so contribute to the overall larger remedy for this constituent. For information purposes, carbon tetrachloride monitoring results in the U Plant area wells are provided in this section. See Chapter 4 for an evaluation of the larger carbon tetrachloride remedy.

As explained in Section 3.2.3.2 for WMA S-SX, carbon tetrachloride is widespread throughout the 200 West Area (Figure 3-48). Baseline carbon tetrachloride concentrations exceed the 3.4 µg/L cleanup level in all wells in the U Plant area (Table 3-13). The 2016 carbon tetrachloride sample results from monitoring wells in the U Plant area vicinity are compared to baseline concentrations in Table 3-13 and Figure 3-40. Trends in carbon tetrachloride concentrations are mixed. For example, a decline has occurred in 299-W19-48, while substantial increases have occurred at 299-W19-49 and 299-W19-115 (Table 3-13). The August 2016 sample result for 299-W19-34B was 106 µg/L compared to a baseline of 135 µg/L (22% decline). The largest concentration increase, in 299-W19-115 (a replacement well for 299-W19-18), was 220 µg/L in October 2016 compared to a baseline of 10 µg/L (2,100% increase). The maximum concentration during 2016 was 305 µg/L in the February sample from 299-W19-49.

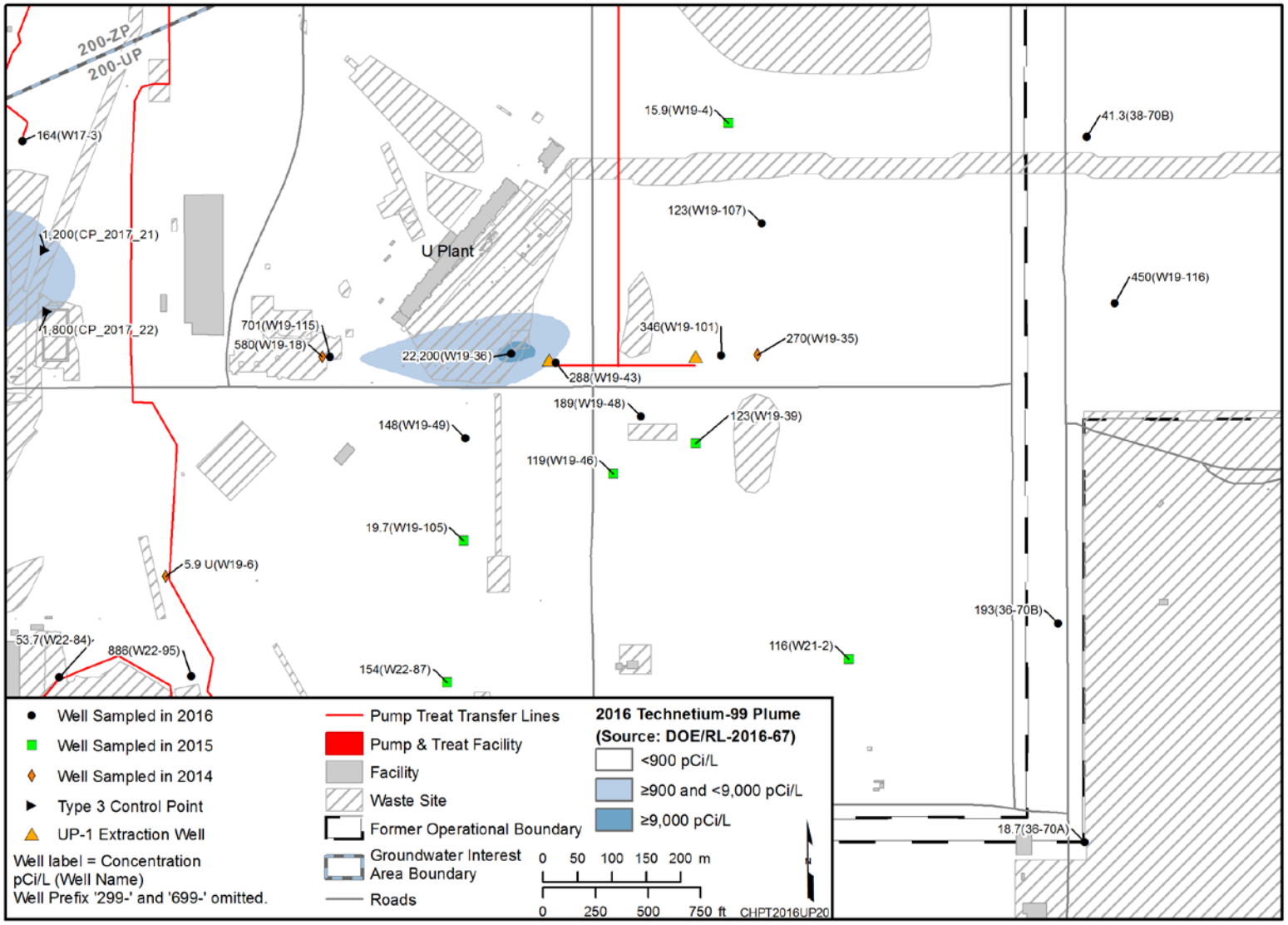


Figure 3-44. U Plant Area Technetium-99 Plume, 2016

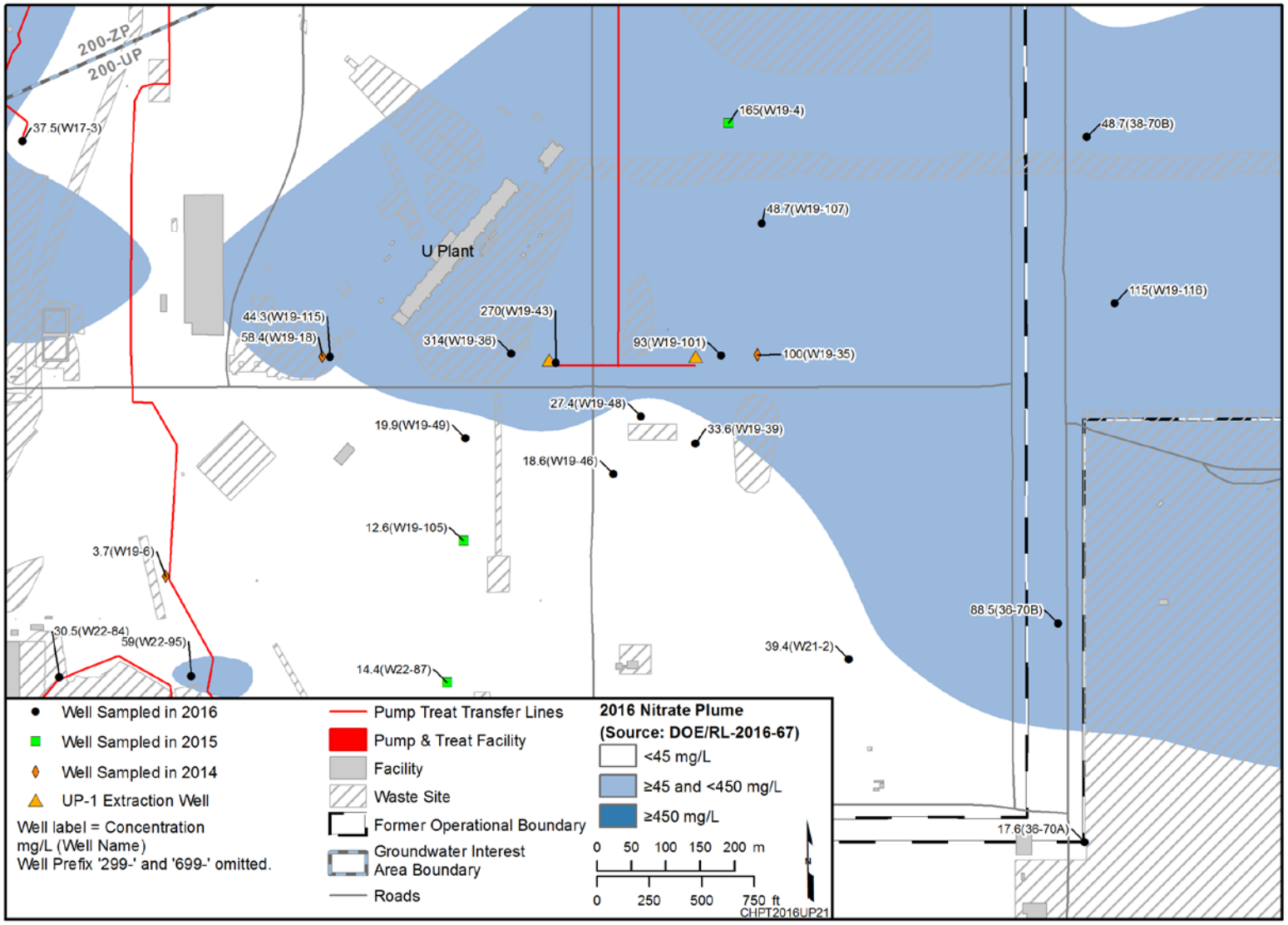


Figure 3-45. U Plant Area Nitrate Plume, 2016

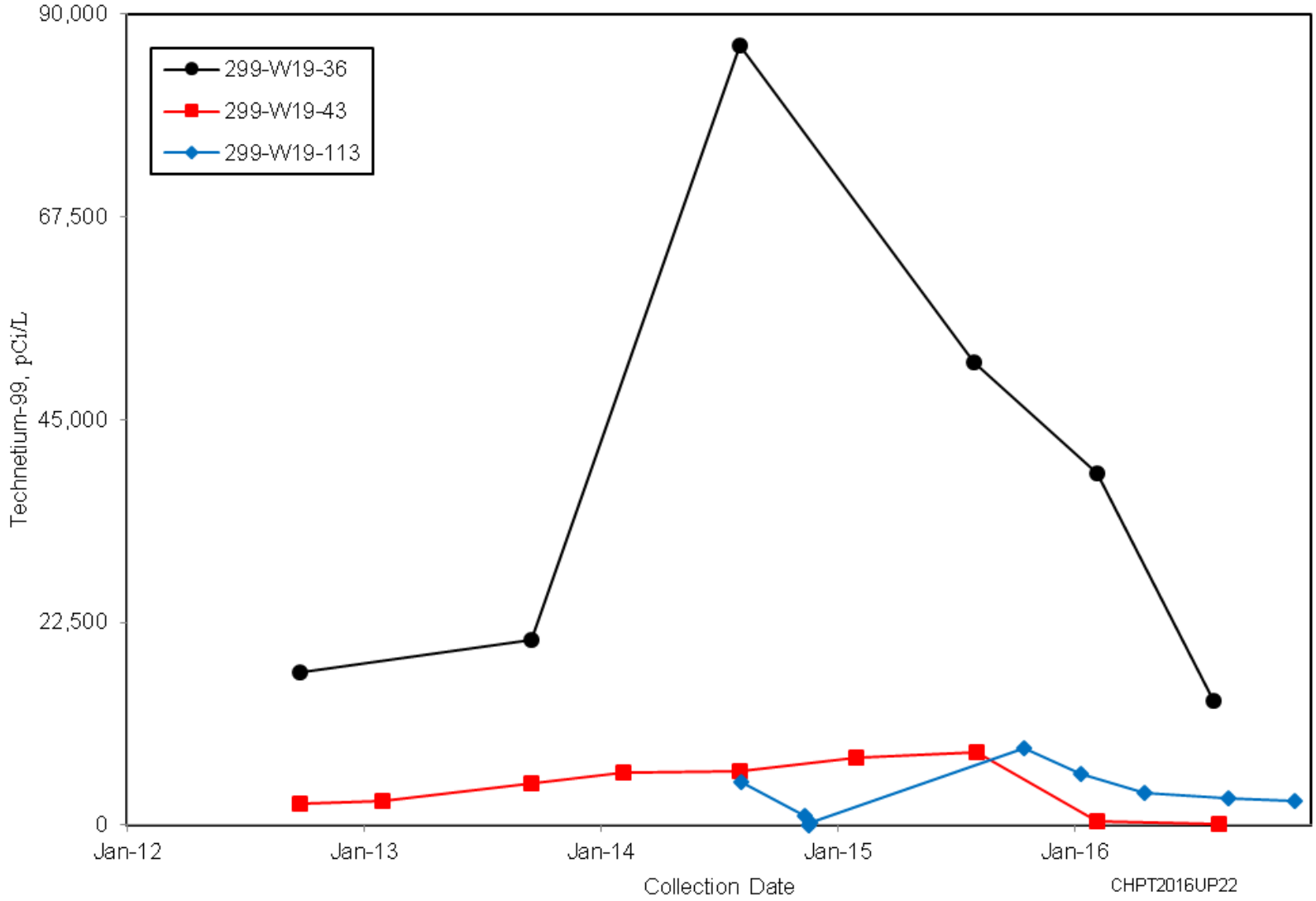


Figure 3-46. Technetium-99 Concentrations in Selected Wells at the U Plant Area P&T System

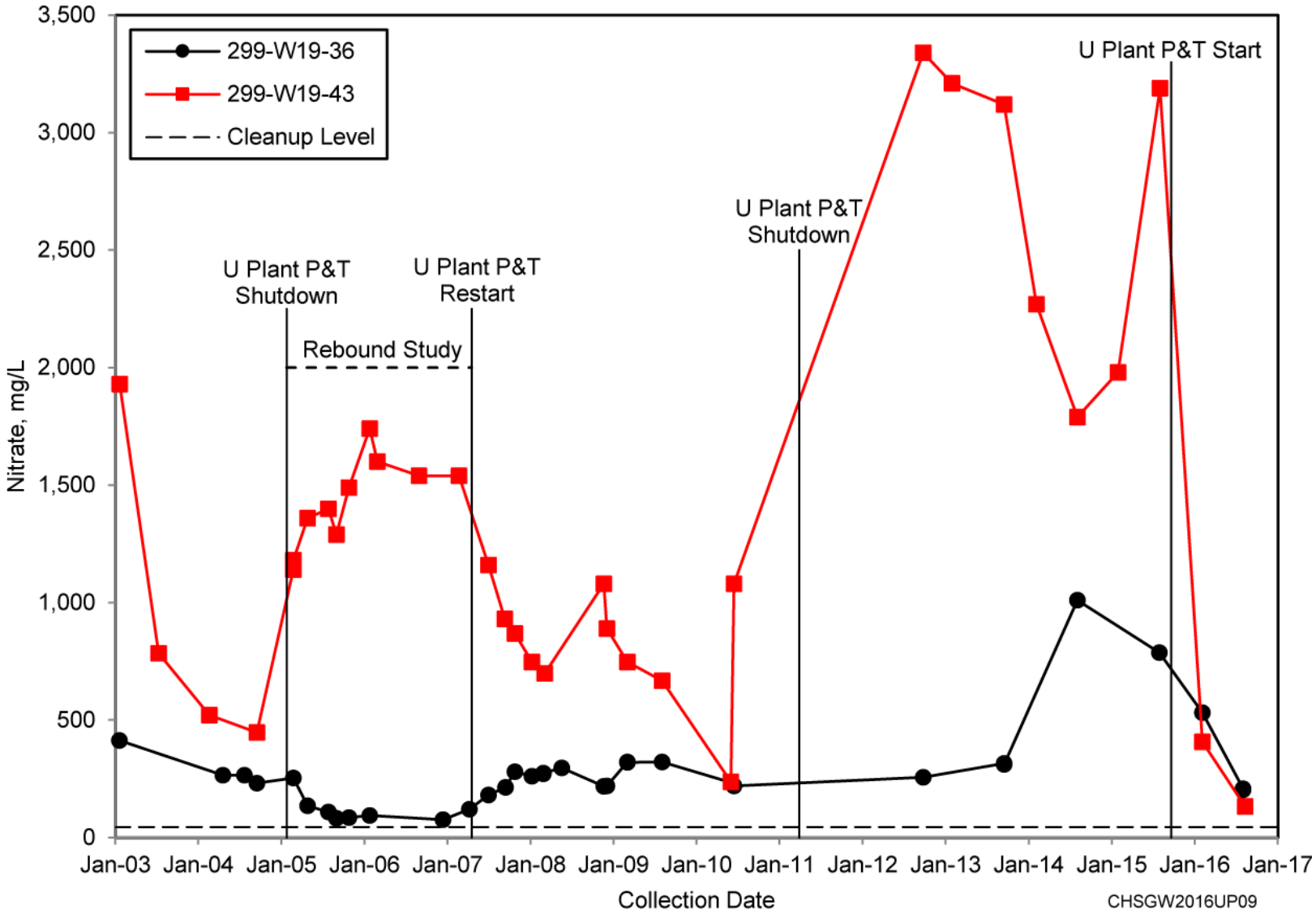


Figure 3-47. Nitrate Concentrations in Selected Wells at the U Plant Area P&T System

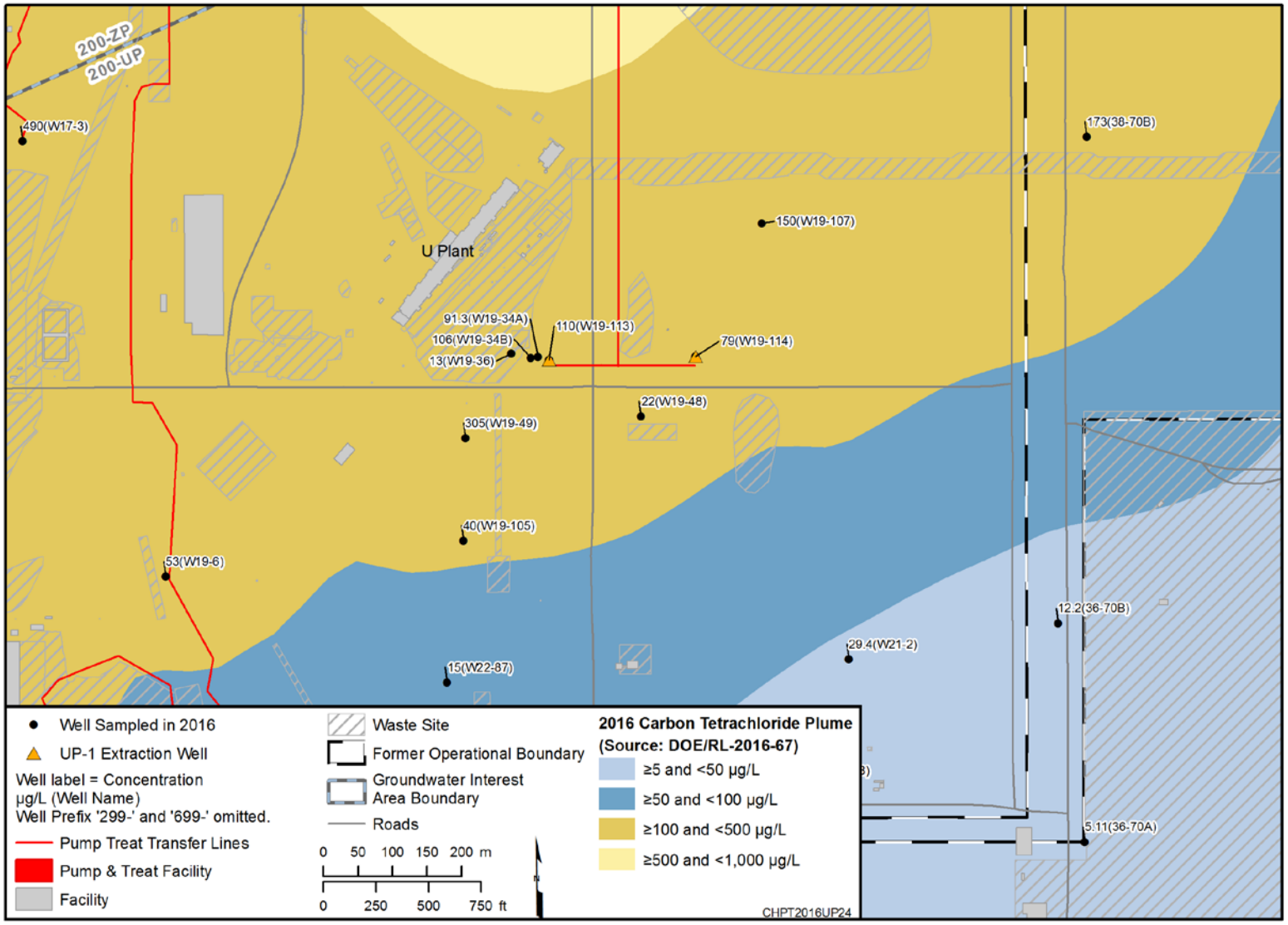


Figure 3-48. U Plant Area Carbon Tetrachloride Plume, 2016

3.3.3.4 Performance Monitoring Calculations

Progress toward achieving cleanup levels for the U Plant area plumes was also evaluated by calculating the UCL_{95} on mean plume concentrations, as described in DOE/RL-2013-07 and DOE/RL-2015-14. The calculations were performed for uranium, technetium-99, and nitrate from 2008 through 2016. The calculations used a minimum of 20 sample results, and data from the previous 2 years were used as needed to ensure a sufficient number of samples. The wells used for the calculation are identified in DOE/RL-2015-14 and are primarily within the footprint of the baseline plumes.

Calculations of UCL_{95} for 2008 through 2016 are shown in Figure 3-49 for uranium and Figure 3-50 for technetium-99 and nitrate. The UCL_{95} values range between 160 and 320 µg/L for uranium; 1,710 and 18,820 pCi/L for technetium-99; and 270 and 1,220 mg/L for nitrate (the respective cleanup levels are 30 µg/L for uranium, 900 pCi/L for technetium-99, and 45 mg/L for nitrate). Concentrations rebounded to higher levels for all three constituents after the second P&T system was shut down in 2011. The 2016 UCL_{95} values are 313 µg/L for uranium; 18,820 for technetium-99; and 1,040 for nitrate.

3.4 Iodine-129 Plume Hydraulic Containment System

The REDOX Plant cribs were the primary sources of an iodine-129 plume that occurs in a region extending 2.3 km (1.4 mi) east from the southeastern 200 West Area (Figure 3-51). The selected remedy for this plume is hydraulic containment while treatment technologies are evaluated (EPA et al., 2012). Hydraulic containment is achieved by injection wells for the 200 West P&T to the east of the iodine-129 plume boundary. Operation of these wells is to contain the plume by increasing the water table elevation downgradient of the plume to slow its eastward migration. Numerical modeling indicated that three wells located downgradient of the plume with injection rates of 189 to 379 L/min (50 to 100 gpm) per well will be sufficient for hydraulic containment. The injected water is post-treatment effluent from the treatment system, and average concentrations in the water meet all of the cleanup levels specified in the 200-UP-1 ROD (EPA et al., 2012; Chapter 2, Section 2.2.4, Table 2-6).

3.4.1 Remedial System Operation

The three hydraulic control injection wells (299-E11-1, 299-E20-1, and 299-E20-2) were drilled during 2015 and began operating on October 28, 2015. The well locations in relation to the iodine plume are shown in Figure 3-51. Periodically, injection was temporarily ceased during 2016 for system maintenance; the longest of these instances lasted 34 days in well 299-E20-2 from August 11 to September 14, 2016. However, the system operated more than 84% of the time during 2016.

The iodine-129 plume hydraulic containment injection wells were designed to operate at a minimum nominal flow rate of 190 L/min (50 gpm) to a maximum of 380 L/min (100 gpm) per well. During 2016, 299-E20-1 operated at an average rate of 173 L/min (45.8 gpm), 299-E20-2 operated at an average rate of 129 L/min (34.2 gpm), and 299-E11-1 operated at an average rate of 203 L/min (53.8 gpm). The combined average flow rate for all three wells was 506 L/min (133.8 gpm) or 89% of the minimum nominal flow rate. The lower than nominal flow rates to the injection wells was a result of reduced flows through the 200 West P&T from April through June for repairs to FBR-A, repair of leaks in the injection transfer building in August, and air-stripper tower cleaning in October. The flow rates outside these maintenance periods in 2016 were 222 L/min (58.7 gpm) for 299-E20-1, 204 L/min (53.8 gpm) for 299-E20-2, and 238 L/min (62.9 gpm) for 299-E11-1. The total volume of water injected into the aquifer during 2016 was 336.9 million L (89.0 million gal).

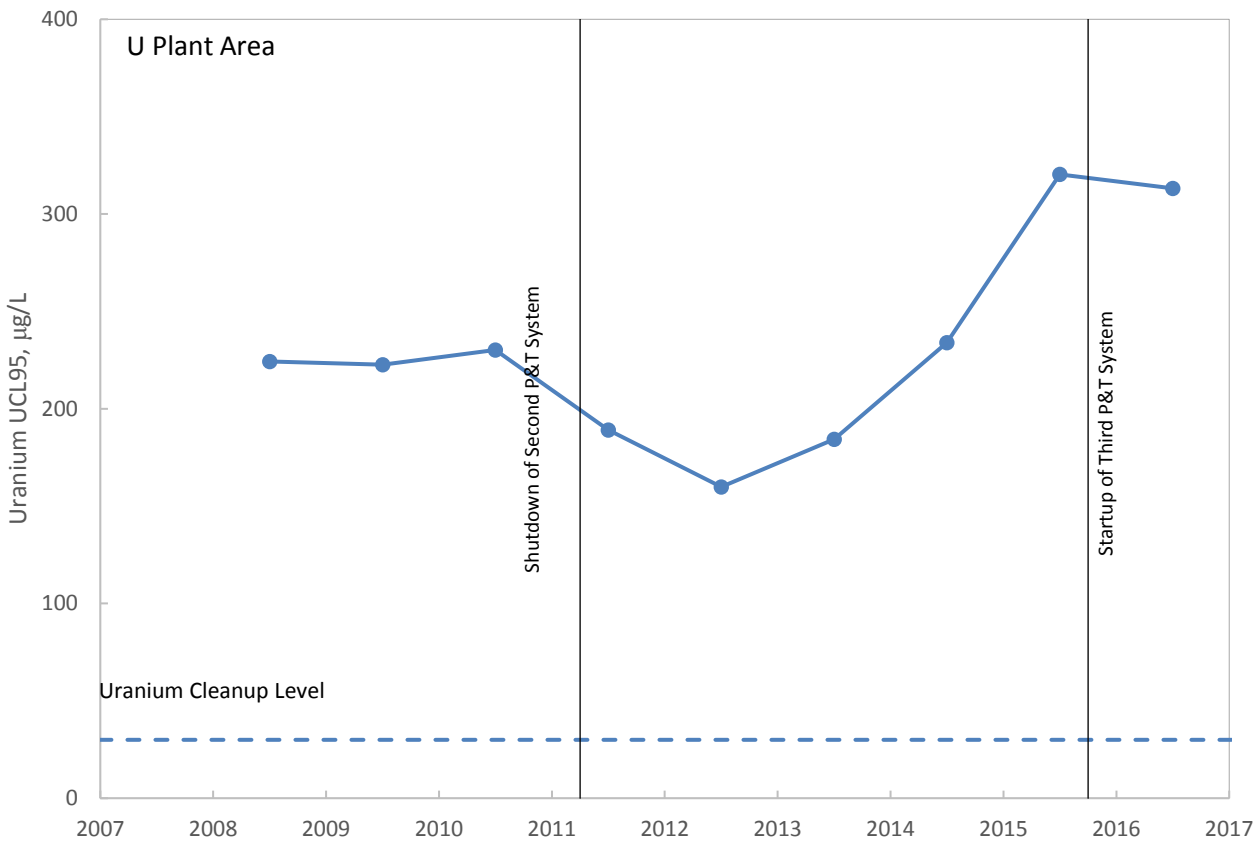


Figure 3-49. Upper Confidence Limits (95th Percentile) on the Mean Concentration of Uranium for the U Plant Area P&T System

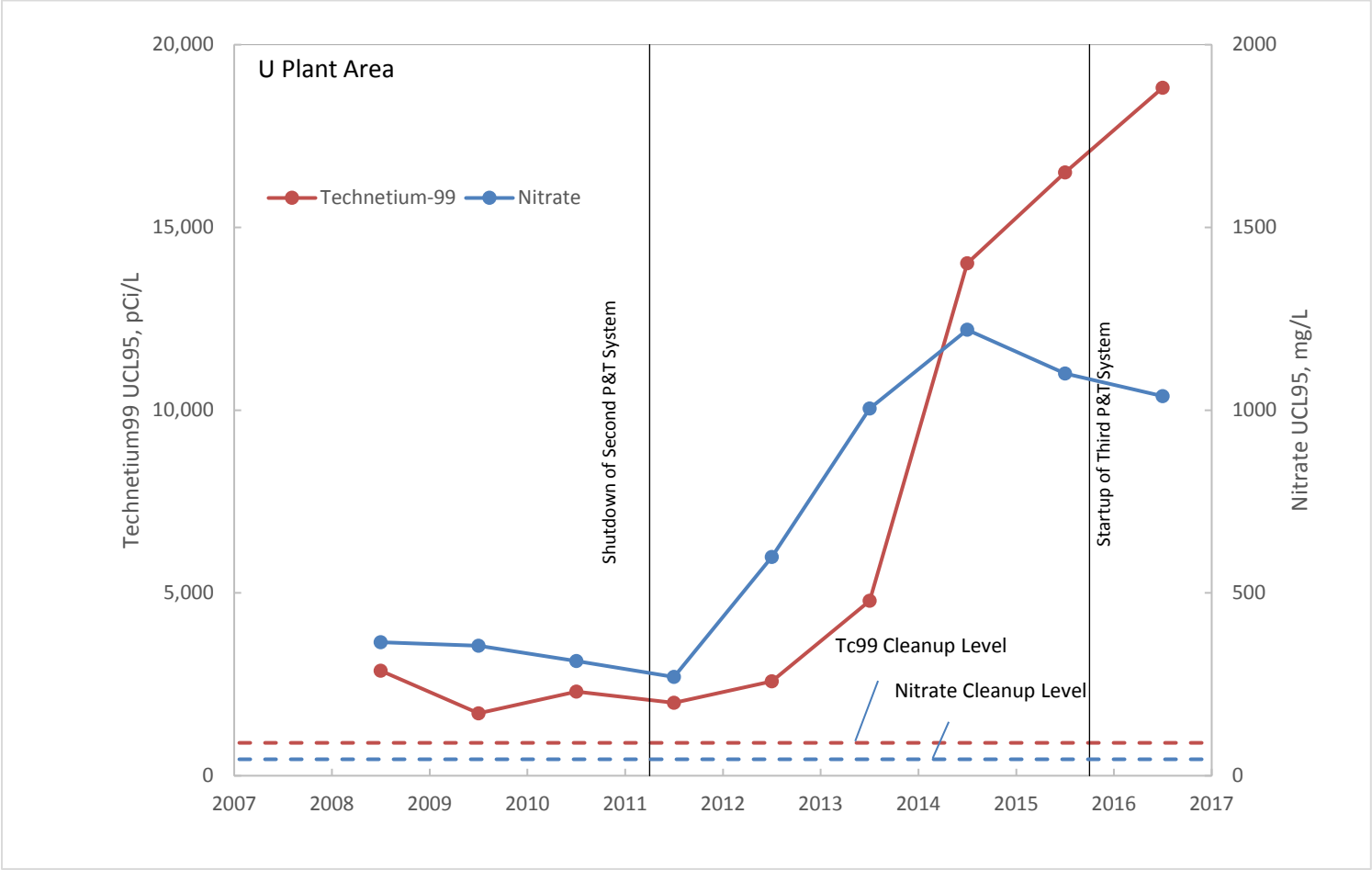


Figure 3-50. Upper Confidence Limits (95th Percentile) on the Mean Concentrations of Technetium-99 and Nitrate for the U Plant Area P&T System

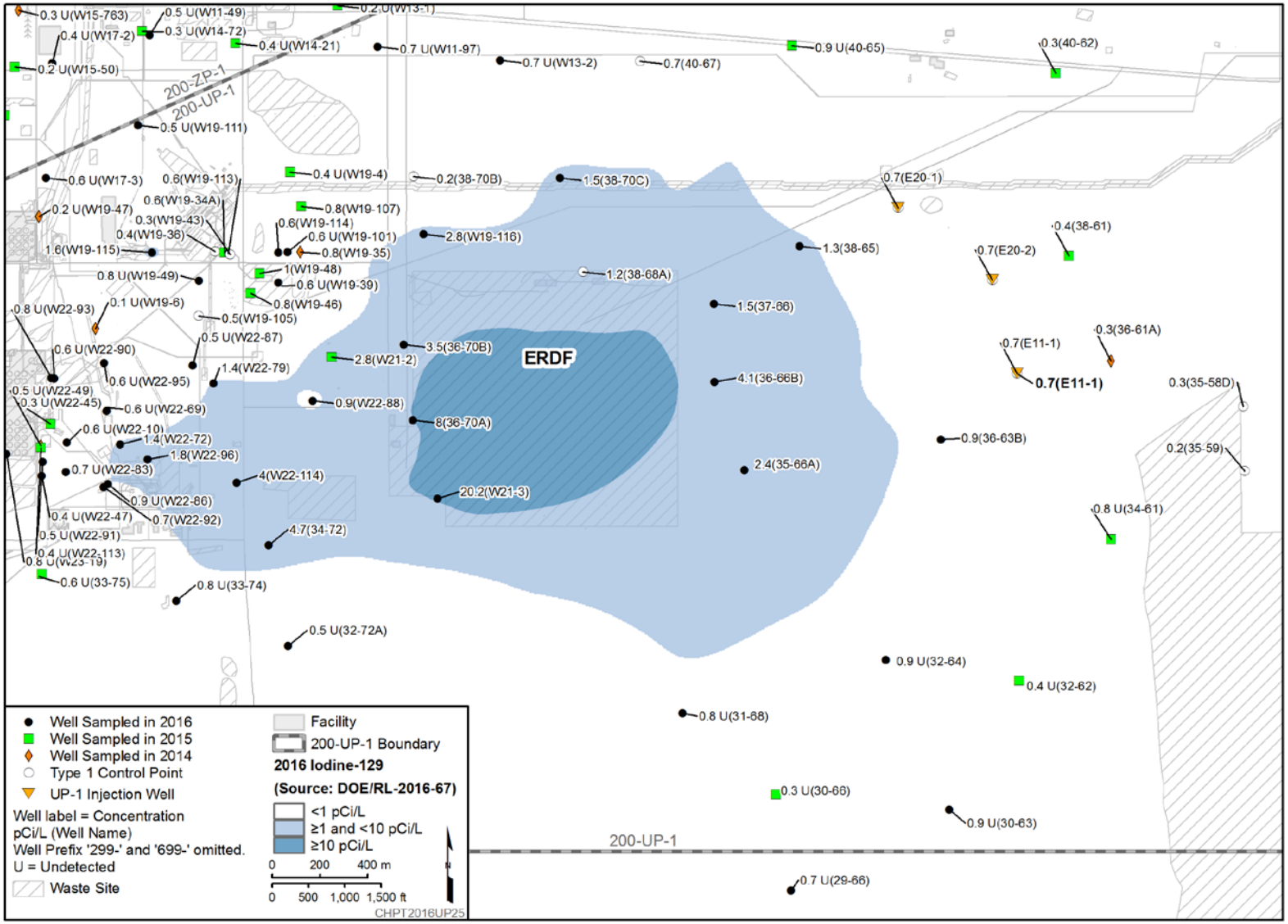


Figure 3-51. Iodine-129 Plume, 2016

3.4.2 Water Level Monitoring

Water level measurements will be used to determine the effectiveness of the hydraulic control remedy. The collection of monthly water level measurements began in September 2015 from a network of wells in the vicinity of the injection wells (Figure 3-3). The wells are located southeast, east, north, and west of the injection wells. The wells nearest to the injection wells are 699-38-61 (340 m east of 299-E20-2) and 699-36-61A (400 m east of 299-E11-1). A new well (699-36-63B) was drilled at the end of 2016, which will be used for hydraulic control monitoring, 425 m southwest of 299-E11-1 (Figure 3-3). Developed by MEUK, the water table is shown in Figure 3-52 for December 2016. Small groundwater mounds are evident around the injection wells. The groundwater flow direction is toward the east-northeast, and the magnitude of the hydraulic gradient is large, as shown by the close spacing of the water table contours. As explained in Section 3.1, the larger gradient magnitude is caused at least in part by a decrease in aquifer thickness and the resulting decrease in transmissivity. The RLM unit, which forms the base of the unconfined aquifer, increases in elevation toward the east resulting in a thinner aquifer. The hydraulic conductivity of the aquifer sediments may also decrease toward the east, which would also contribute to the reduced transmissivity and larger hydraulic gradient.

Evaluation of the hydraulic control remedy considers the development of reduced hydraulic gradients to the northeast of the iodine-129 plume. The methods used in preparation of this CY 2016 annual report are detailed in ECF-200W-17-0029, *Description of Groundwater Calculations and Assessments for the Calendar Year 2016 (CY 2016) 200 Areas Pump and Treat Report* (pending). Figures 3-53 and 3-54 depict the mapped and simulated hydraulic gradients, respectively. The arrow on the figures indicates the gradient direction, and arrow length indicates the gradient magnitude. Because natural gradients in this area would be toward the east, the hydraulic gradient absent the groundwater P&T would produce arrows pointing toward the east as depicted in the left panel a in each figure (representing baseline conditions). The gradient direction and magnitude under current conditions is depicted by arrow orientation and length in the right panel b in each figure. Larger changes in gradient direction and magnitude due to injection of treated effluent are evidenced by larger differences in the arrow direction and length between the a and b panel figures. The greatest gradient magnitude and direction changes are observed near the injection wells. Direction changes are depicted in the right panel b figures by coloring; a change in the gradient from east to west is colored red, whereas a change in gradient (or increase in gradient in the same direction) is depicted in green. Gradient changes as expected are less evident moving further away from the injection wells. The effectiveness of the hydraulic control remedy for iodine-129 plume containment will be evaluated in greater detail after the 200 West P&T has been running at full capacity for a sufficient time to stabilize hydraulic gradients. As of 2016, the iodine-129 hydraulic control injection wells have operated only 1 year.

3.4.3 Contaminant Monitoring

The maximum sample result in the iodine-129 plume during 2016 was 20.2 pCi/L in 299-W21-3, a replacement well for 699-35-70 completed in July 2016. High concentrations also occurred in 299-W22-114 of 3.37 pCi/L, replacement well for 299-W22-9, completed in November 2016 and located along the eastern boundary of the 200 West Area. Well 299-W22-9 became dry during 2006; the iodine-129 concentration was 30 pCi/L when this well was last sampled in 2005.

Depth-discrete water samples were collected from the aquifer during drilling of the injection wells, and the results are shown in Table 3-15. Concentrations of iodine-129 were below the 1 pCi/L cleanup level in all the samples from 699-36-63B, but concentrations were above the cleanup level in each sample in 299-W21-3 and in the three uppermost samples from 299-W22-114. Baseline groundwater samples were collected from the constructed wells prior to the startup of injection, and the results are shown also in Table 3-12. The baseline samples from two wells, 299-W21-3 and 299-W22-114 (20.2±1.6 and 3.37±1.0 pCi/L, respectively), were above the cleanup level.

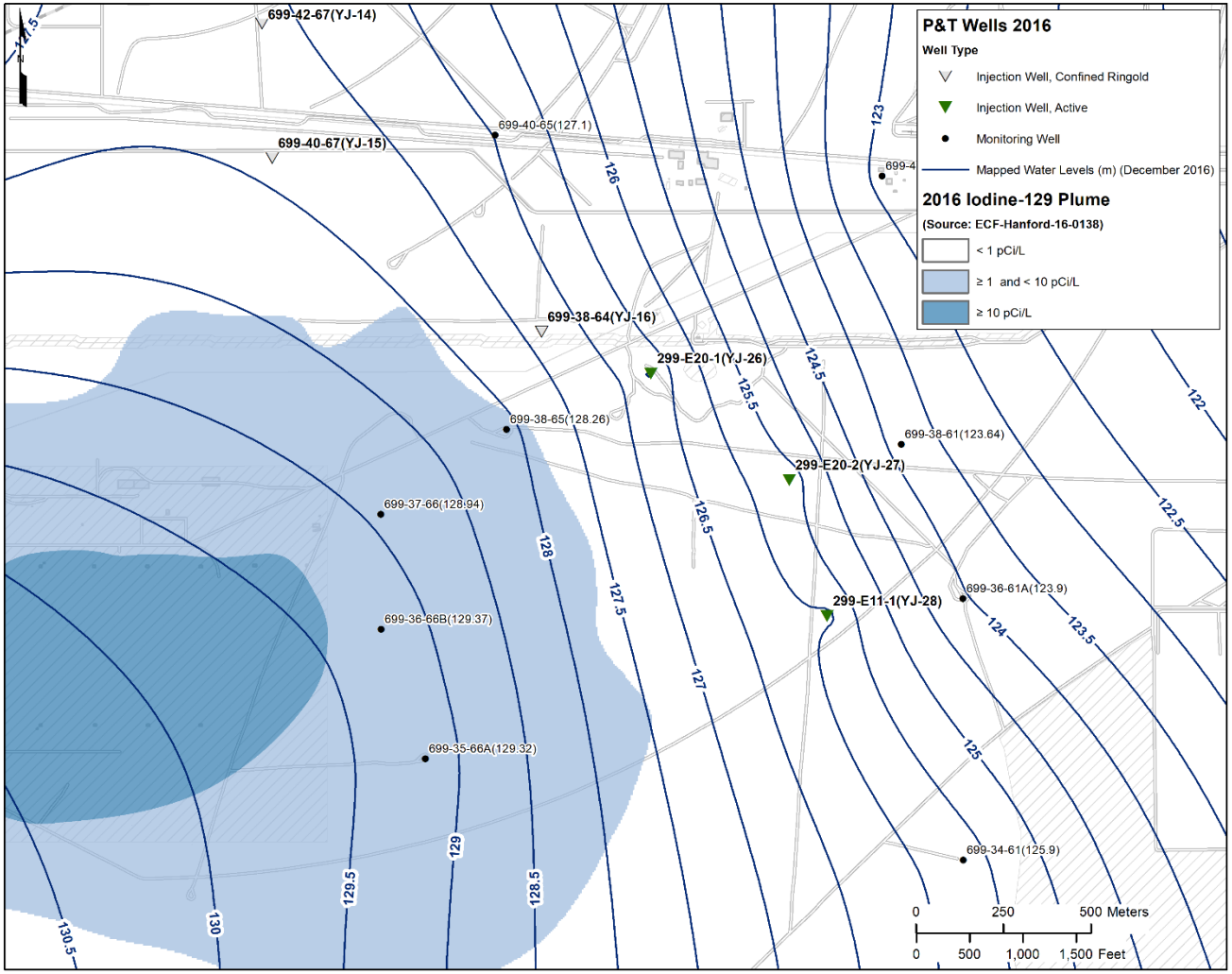


Figure 3-52. Water Table for the Iodine-129 Plume Hydraulic Containment Remedy, December 2016

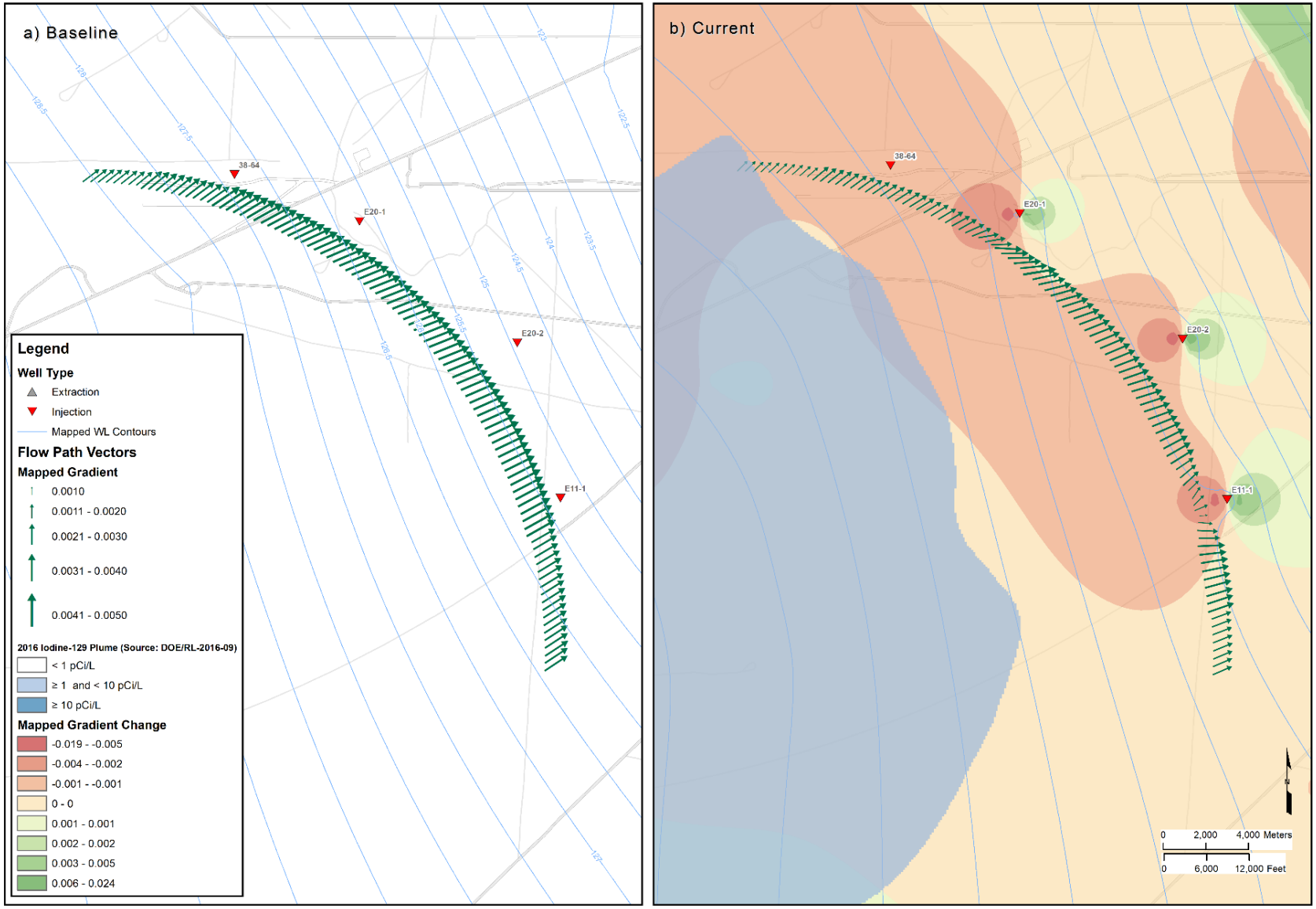


Figure 3-53. Mapped Gradient Changes along Line of Control

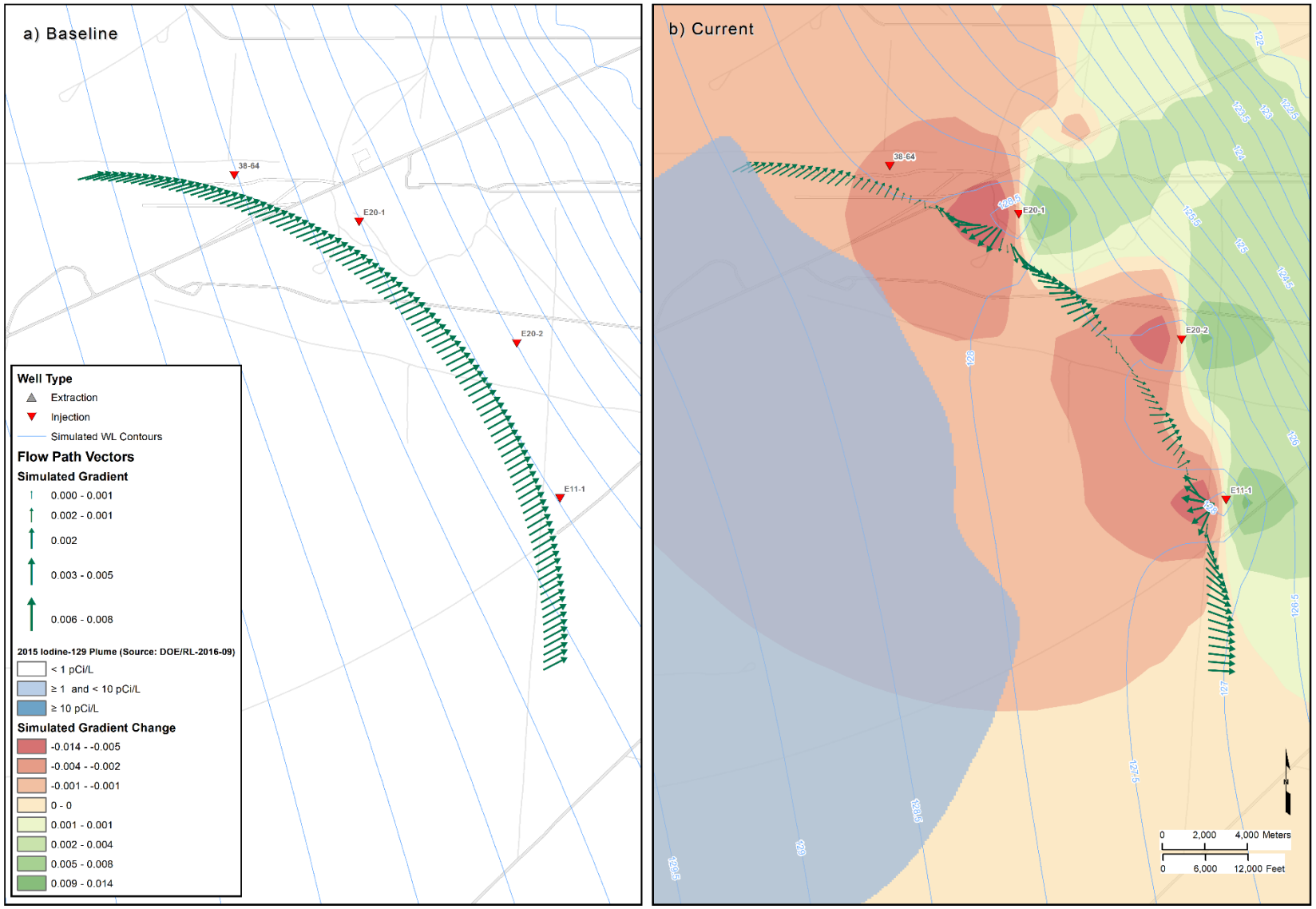


Figure 3-54. Simulated Gradient Changes along Line of Control

Table 3-15. Depth Profile Sample Results for the Iodine-129 Plume Wells

Well Name	Depth (ft below water table)	Nitrate (mg/L as NO_3)	Iodine-129 (pCi/L)	Tritium (pCi/L)
299-W21-3	4.8	26.6	14.1 (±1.9)	39,900
	48.9	20.8	38.9 (±5.0)	133,000
	69.6	21.7	7.14 (±1.3)	128,000
	99.9	22.6	14.5 (±2.1)	130,000
	128.7	18.6	3.7 (±1.1)	70,900
	149	16.8	2.31 (±0.91)	53,900
	Baseline sample	20.8	20.2 (±1.6)	82,900
299-W22-114	10.6	79.7	4.01 (±0.84)	33,700
	34.1	5.31	1.73 (±0.55)	35,500
	67.4	4.4	1.49 (±0.72)	11,200
	97.7	3.5	0.304U (±0.77)	2,410
	127.6	3.9	0.496U (±0.37)	331
	177.6	6.2	0.261U (±0.3)	-171U
	197.3	7.5	0.048U (±0.21)	1.72U
	Baseline sample	66.4	3.37 (±1.0)	28,600
699-36-63B*	7.41	21.7	0.678 (±0.65)	87,500
	17.25	19.5	0.615U (±0.62)	89,600
	37.58	19.5	0.848 (±0.27)	106,000
	57.59	19.5	0.284U (±0.47)	102,000
	77.82	18.6	0.110U (±0.46)	75,700
	Baseline sample	18.6	0.776 (±0.7)	90,300

* Dual-use monitoring and hydraulic control injection well.

U = undetected

3.5 Southeast Chromium Plume Characterization

Chromium occurs in groundwater southeast of the 200 West Area at concentrations above the 48 µg/L cleanup level (Figure 3-55). This plume originated primarily from effluent disposal to the 216-S-20 Crib during the 1950s, although the REDOX Plant ponds and ditches south of the 200 West Area were also sources (Section 4.2.4 of DOE/RL-2009-122). An estimated 5,900 kg of chromium was disposed to the 216-S-20 Crib, and an estimated 3,000 kg was disposed to the 216-S-10 Pond and Ditch (Appendix C in RPP-26744, *Hanford Soil Inventory Model, Rev. 1*). The plume is essentially fully mixed vertically in the aquifer. The concentration in 699-30-66, screened deep in the aquifer just above the RLM unit, was 110 µg/L during 2016. This is similar to the concentration of 140 µg/L in 699-32-62, located 1.1 km (0.7 mi) northeast of 699-30-66 and screened across the water table.

The selected remedy for the southeast chromium plume is a combination of P&T and MNA (EPA et al., 2012). To design the P&T system, additional information is needed regarding plume extent. The northern and northeastern extents of the plume are well constrained by existing wells, but the western and southern extents are uncertain. Also, more information is needed to define the higher concentration (i.e., concentrations greater than 100 µg/L) portion of the plume more accurately.

To reduce the uncertainty in the extent of the chromium plume, three characterization wells were drilled in 2016 and seven additional characterization wells are planned to be drilled in 2017. The purpose of the three wells (699-29-66, 699-30-57, and 699-31-68) drilled in 2016 is to define the extent of contamination at the 48 µg/L concentration level (the cleanup level for hexavalent chromium) more accurately. The first three wells (699-30-63, 699-32-59, and 699-32-64) to be drilled in 2017 are to provide a more accurate definition of the extent of the higher concentration portion of the plume at the 100 µg/L concentration level (i.e., the cleanup level for total chromium). The objective of the four remaining wells to be drilled in 2017 is to define the southern, western, and eastern extents of contamination at the 48 µg/L concentration level more accurately (Figure 3-55).

Depth-discrete water samples were collected from the aquifer during drilling of the 2016 monitoring wells (Table 3-16). Concentrations of total chromium were below the 100 µg/L cleanup level in all the samples from 699-31-68 and 699-29-66, but above the cleanup level in the uppermost sample in 699-30-57. The 110 µg/L result at 699-30-57 was higher than expected because it was sited near the edge of the interpreted 48 µg/L plume contour. Based on the higher concentration found during drilling at 699-30-57, additional sampling was performed in existing wells in the area. Based on those results, four additional characterization wells were planned to be drilled in 2017 (Figure 3-55). Baseline groundwater samples were collected from the constructed wells, and the results are also shown also in Table 3-16. The baseline samples from well 699-30-57 (100 µg/L) was at the cleanup level for total chromium. The baseline samples from two wells, 699-29-66 and 699-30-57 (86 and 100 µg/L, respectively), were above the cleanup level (48 µg/L) for hexavalent chromium.

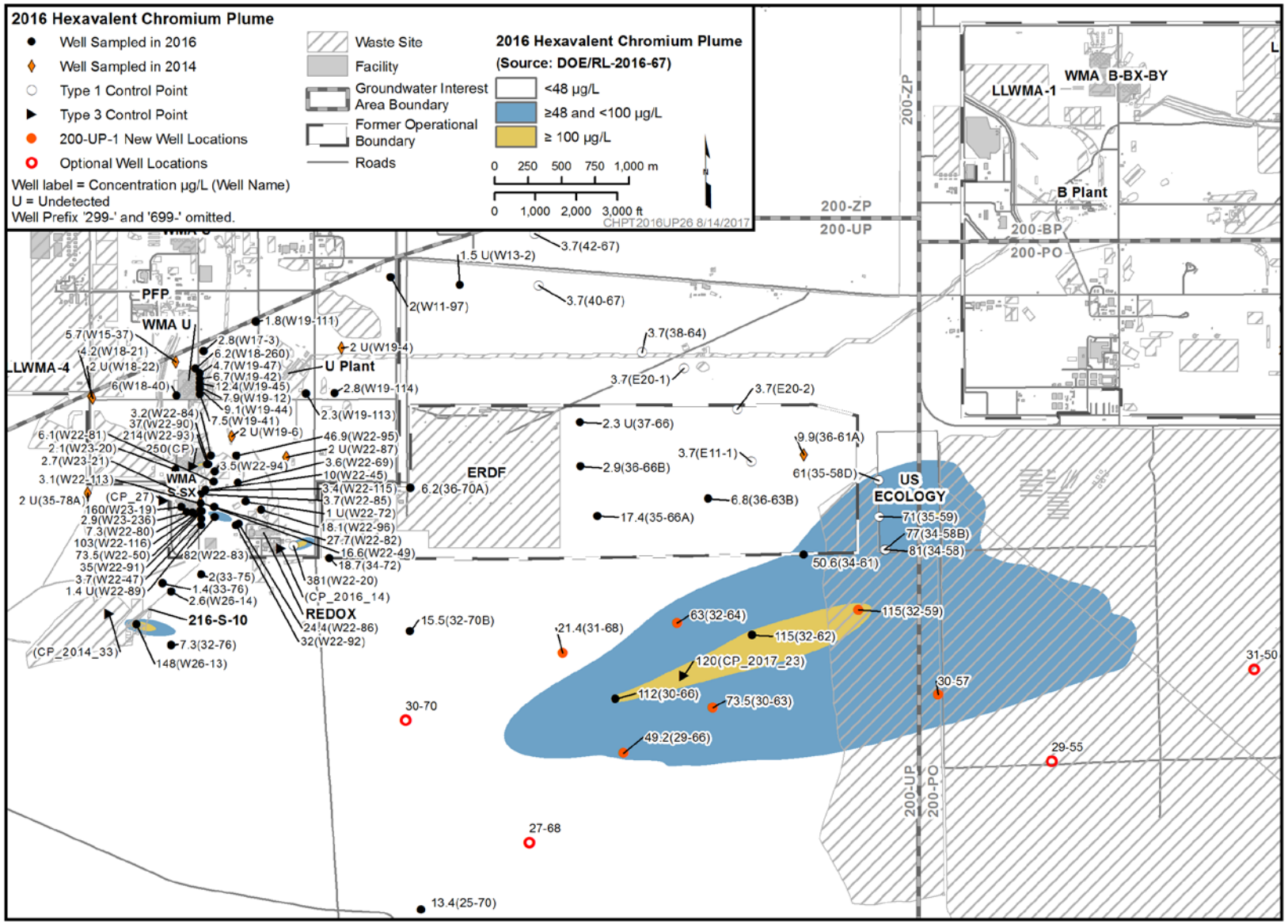


Figure 3-55. Characterization Wells for the Southeast Chromium Plume

Table 3-16. Depth Profile Sample Results for the SE Chromium Plume Monitoring Wells

Well Name	Depth (ft below water table)	Total Chromium (µg/L)	Hexavalent Chromium (µg/L)
699-29-66	23.7	13	11
	82.2	56	55
	152.0	1.1 U	1.5 U
	240.9	1.1 U	1.6
	Baseline sample	50.3	86
699-30-57	31.9	110	99
	84.7	28	20
	Baseline sample	100	100
699-31-68	40.4	18	15
	80.2	4.2	2.7
	150.4	23	20
	Baseline sample	26	26

Note: Wells were screened near the top of the water table.

U = undetected

3.6 Monitored Natural Attenuation

MNA is specified in the 200-UP-1 ROD (EPA et al., 2012) used in conjunction with active remedies or as a standalone remedy in the case of tritium to achieve RAOs. Two primary MNA mechanisms were identified, dispersion for all COCs and radiological decay for tritium, which are supported by the fate and transport modeling performed for the RI/FS (DOE/RL-2009-122). These indicated that the portion of plumes not affected by planned active remedies will disperse or decay naturally to below cleanup levels within 125 years.

MNA is evaluated statistically by calculating the one-sided UCL_{95} on the mean of the plume concentrations as specified in the RD/RAWP (DOE/RL-2013-07) and PMP (DOE/RL-2015-14). This section presents the UCL_{95} values for tritium and nitrate regionally across the 200-UP-1 OU. The calculations used a minimum of 20 sample results, primarily from 2016, but data from 2015 were included as needed to ensure a sufficient number of samples. Wells used for the calculations are identified in DOE/RL-2015-14. Wells used for the tritium UCL_{95} are primarily within the baseline plume footprint for tritium throughout the OU (i.e., have baseline concentrations above the 20,000 pCi/L cleanup level). The wells used for the nitrate UCL_{95} are those within the baseline plume footprint for nitrate throughout the OU (i.e., baseline concentrations are above the 45 mg/L cleanup level), excluding the U Plant and WMA S-SX remedy areas. UCL_{95} values (technetium-99) for the WMA S-SX groundwater extraction system were presented in Section 3.2.3.3, and values (uranium, technetium-99, and nitrate) for the U Plant area P&T system were presented in Section 3.3.3.4. Baseline concentrations from which MNA will be evaluated are shown in Table 3-17 for tritium and Table 3-18 for nitrate. The 2016 tritium and nitrate plume maps for the OU for MNA (Figures 3-56 and 3-57, respectively).

Table 3-17. Tritium Baseline Sample Results for Monitored Natural Attenuation

Well Name	Tritium (pCi/L) [a]
299-W22-113	39,700
299-W22-45	47,200 [b]
299-W22-69	3,130
299-W22-72	15,600
299-W22-83	4,720
299-W22-86	9,350
299-W22-88	7,660
299-W22-96	12,600
299-W23-19	10.500
299-W23-21	16,500
299-W23-4	50,300
699-32-62	5,330 [c]
699-32-72A	38,100
699-33-74	15,100
699-34-61	8,380
699-34-72	9,610
699-35-66A	69,000
699-36-61A	41,200
699-36-66B	250,000
699-36-70A	42,400
699-36-70B	7,090
699-37-66	53,200
699-38-61	71,000
699-38-65	53,900 [c]
699-38-68A	11,900
699-40-62	4,450

a. Sampled during 2016 unless otherwise noted.

b. Sampled during June 2015.

c. Maximum of duplicate sample results.

Table 3-18. Nitrate Baseline Sample Results for Monitored Natural Attenuation

Well Name	Nitrate (mg/L) [a]
299-W15-37	84.1
299-W18-15	58.4 [b]
299-W18-21	31.9
299-W18-40	79.7
299-W19-44	48.7
299-W19-45	128
299-W19-47	70.8
699-36-66B	53.1 [c]
699-36-70B	88.5
699-37-66	146
699-38-65	164 [c]
699-38-68A	159
699-38-70C	124
699-40-62	115
699-40-65	212

a. Sampled during 2016.

b. Sampled during January 2015.

c. Maximum of duplicate sample results.

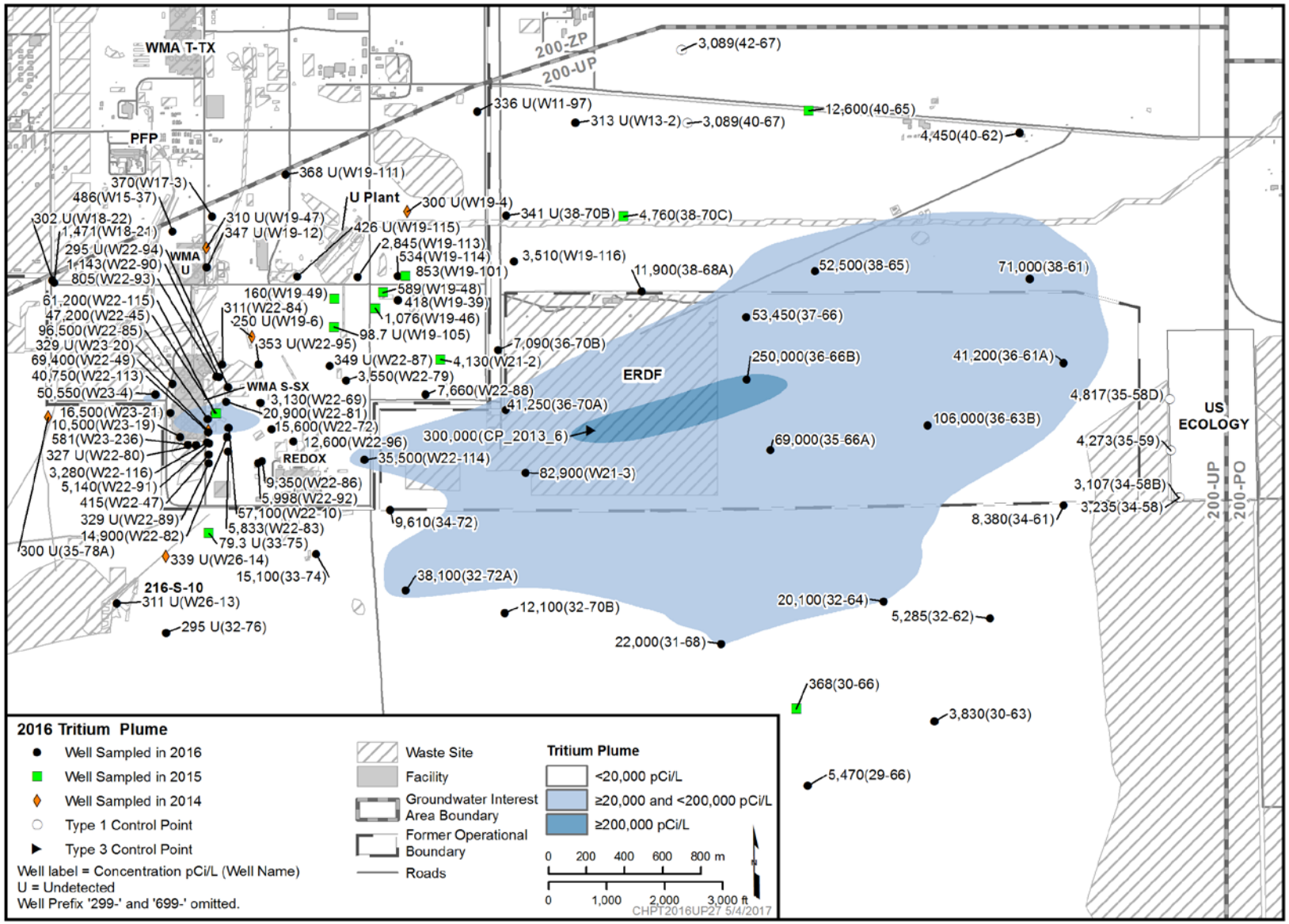


Figure 3-56. 200-UP-1 Tritium Plume Map, 2016

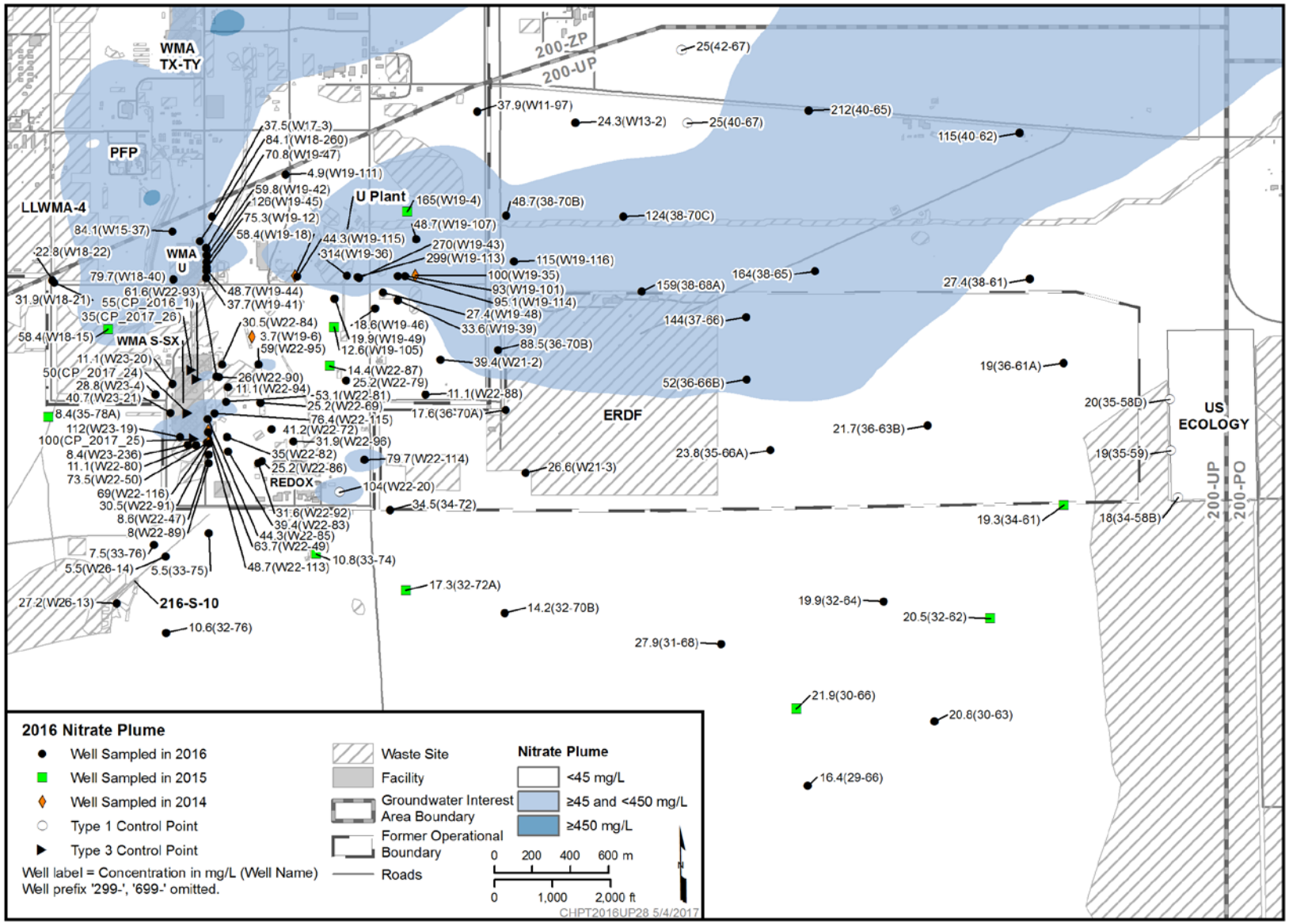


Figure 3-57. 200-UP-1 Nitrate Plume Map, 2016

UCL_{95} values for tritium and nitrate from 2008 to 2016 are shown in Figure 3-58. The tritium UCL_{95} values range between 50,100 and 90,500 pCi/L. The decline from 2008 to 2009 was due to the loss of 699-35-70 from the network because it became dry. This well was located in a high-concentration portion of the tritium plume (replacement well 299-W21-3 was drilled in 2016). The increase from 2011 to 2012 results from the addition of 699-36-66B to the network, which is a downgradient monitoring well for ERDF and within the high-concentration portion of the plume. The decline in UCL_{95} values from 2012 to 2015 is probably due to dispersion and radiological decay of the plume. The increase from 2015 to 2016 results from the addition of 699-35-66A to the network, which is a downgradient monitoring well for ERDF and near the high-concentration portion of the plume.

The nitrate UCL_{95} values range between 93 and 130 mg/L and exhibit a slight upward trend (Figure 3-58). The increasing trend is attributed to increasing nitrate concentrations at the U Tank Farm. Some of the increasing concentrations may be due to nitrate from the tank farm, but concentrations are also increasing in the upgradient well (299-W18-40). The upgradient source is interpreted to be the injection wells formerly used for the 200-ZP-1 interim action P&T system (Section 3.3.5 of DOE/RL-2011-118). Treatment for that system consisted of air stripping to remove volatiles. The extracted water contained nitrate, which was not removed by the treatment process and was injected into the aquifer upgradient of the U Tank Farm.

3.7 Quality Assurance/Quality Control

Discussion on the QA/QC encompassing sampling and analysis of the 200-UP-1 OU wells is provided in Appendix E of DOE/RL-2016-67. The discussion includes an overall view of QA/QC issues that may affect interpretation of the groundwater data presented in this report.

3.8 Remedial System Costs

Tables 3-19 through 3-22 present the cost breakdown for the WMA S-SX groundwater extraction system, U Plant area P&T system design and construction, iodine-129 plume hydraulic containment design and construction, and southeast chromium plume characterization for 2016. Costs are burdened and are based on actual operating costs incurred during 2016. The specific cost categories listed are as follows:

- **Design**: Consists of labor, equipment, material, and subcontractor costs for design of the remedial systems. Design costs include all design documentation (drawings, calculations, and specifications), engineering studies, permitting, aquifer response numerical modeling, and associated activities.
- **Construction**: Consists of the costs of constructing the remedy, including labor, equipment, material, and subcontractor costs. Costs are included for installation of extraction and injection wellhead mechanical and electrical racks, pipelines, transfer buildings, connections to the treatment facility, associated equipment and utilities, and acceptance testing prior to turnover to operations. Construction of the WMA S-SX groundwater extraction system was started in 2011 and completed in 2012. Construction of the U Plant area P&T system and design for the iodine-129 plume hydraulic containment system were initiated in 2014. Construction of both systems was completed during 2015.
- **Project support**: Consists of labor, equipment, material, and subcontractor costs for project management and support associated with implementation of the remedial action. It includes management of project scope, schedule, and budget. It also includes project oversight/coordination of planning, regulatory documentation, remedial design, construction, operations, and monitoring activities.

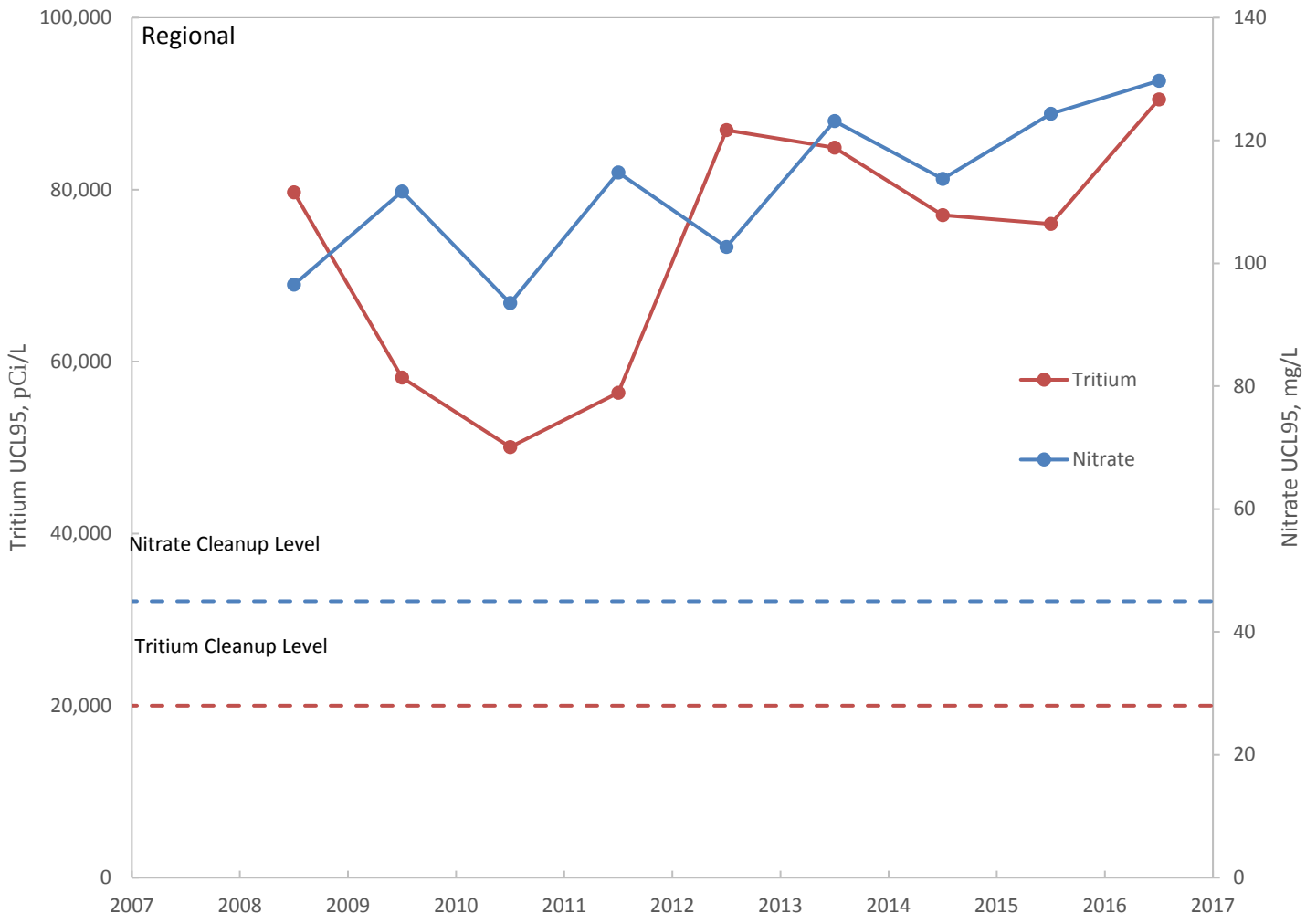


Figure 3-58. Upper Confidence Limits (95th Percentile) on the Mean Concentrations of Tritium and Nitrate for the 200-UP-1 OU

Table 3-19. Cost Breakdown for the WMA S-SX Groundwater Extraction System

Description	Actual Costs (in thousands)						
	2010	2011	2012	2013	2014	2015	2016
Design	$250.0	--	--	--	--	--	--
Construction	$1,378.9	$3,952.5	$178.7	--	--	--	--
Project support	$7.6	$155.4	$0.9	$9.1	$3.3	$7.7	$12.3
Operations and maintenance *	--	--	$715.8	$1,084.2	$727.5	$506.9	$402.3
Performance monitoring	--	$17.3	$12.7	$53.7	$62.7	$40.8	$84.2
Well installation	--	$1,177.4	--	--	--	--	--
Totals	**$1,636.5**	**$5,302.6**	**$908.1**	**$1,147.0**	**$793.5**	**$555.4**	**$498.8**

* The O&M cost has been adjusted to reflect apportioning the overall 200 West P&T O&M cost to the S-SX extraction system based on the percentage of mass treated from extracted S-SX groundwater to the total mass treated by the 200 West P&T.

Table 3-20. Cost Breakdown for the U Plant Area P&T System

Description	Actual Costs (in thousands)		
	2014	2015	2016
Design	$1,449.5	$69.3	$66.0
Construction	$2,461.4	$6,951.7	--
Project support	$291.3	$81.1	$12.2
Operations and maintenance *	--	$400.4	$592.4
Performance monitoring	$0.0	$12.8	$483.4
Well installation	$781.9	$766.4	$2676.1
Totals	**$4,984.1**	**$8,281.8**	**$3,866.1**

* The O&M cost has been adjusted to reflect apportioning the overall 200 West P&T O&M cost to the U Plant P&T system based on the percentage of mass treated from extracted U Plant groundwater to the total mass treated by the 200 West P&T.

Table 3-21. Cost Breakdown for the Iodine-129 Hydraulic Containment System

Description	Actual Costs (in thousands)		
	2014	2015	2016
Design	$121.3	$130.9	--
Construction	$36.6	$2,004.6	$5.6
Project support	$63.0	$51.6	$12.2
Operations and maintenance *	--	--	$230.5
Performance monitoring	--	--	--
Well installation	$1.6	$2,048.6	$15.1
Totals	**$222.5**	**$4,235.7**	**$263.4**

* The O&M cost has been adjusted to reflect apportioning the overall 200 West P&T O&M cost to Iodine-129 Plume containment based on percentage of wells requiring maintenance.

Table 3-22. Cost Breakdown for Chromium Characterization

Description	Actual Costs (in thousands) 2016
Design	--
Construction	--
Project support	$84.9
Operations and maintenance	--
Performance monitoring	--
Well installation	$2,349.0
Total	**$2,433.9**

- **O&M**: Consists of labor, equipment, and material costs for operational testing and for O&M of the remedial systems. For the 200-UP-1 OU, this includes costs for extraction wells (including wellheads) and transfer building O&M for the WMA S-SX groundwater extraction system. Treatment system costs for the WMA S-SX groundwater extraction system and the U Plant area P&T reflect apportionment of the overall 200 West P&T O&M cost based on the percentage of mass treated from extracted UP-1 groundwater to the total mass treated by the 200 West P&T (Chapter 2, Table 2-14).
- **Performance monitoring**: Consists of labor, equipment, and material costs for remedy performance monitoring of the aquifer typically defined in a monitoring plan. This category addresses the costs for collecting and/or evaluating data to assess changes in contaminant plume geometry, hydraulic controls (including plume capture or containment), and effectiveness of natural attenuation processes. It also includes costs for monitoring water levels and preparing an annual report.
- **Well installation**: This includes costs for the installation of new CERCLA monitoring, extraction, and injection wells at the 200-UP-1 OU.

3.9 Conclusions

The following conclusions are made regarding the remedies in the 200-UP-1 OU:

- The WMA S-SX groundwater extraction system operates at its design capacity. During 2016, the combined pumping rate from the three extraction wells averaged 343 L/min (91 gpm) or 113% of the design nominal pumping rate of 303 L/min (80 gpm).
- During 2016, the WMA S-SX groundwater extraction system extracted 167 million L (44.1 million gal) of water, containing an estimated 22.3 g (0.378 Ci) of technetium-99, 5.4 kg of chromium, 4,910 kg of nitrate, and 11.4 kg of carbon tetrachloride from the aquifer. The total mass removed since startup was 150.9 g (2.56 Ci) of technetium-99; 41.4 kg of chromium; 27,510 kg of nitrate; and 50.9 kg of carbon tetrachloride.
- Technetium-99, chromium, and nitrate concentrations declined in a majority of wells that had baseline concentrations above a cleanup level. UCL_{95} for technetium-99 declined from 20,700 to 9,430 pCi/L between 2011 and 2016 due to operation of the groundwater extraction system.
- During 2016, the first full year of operation of the U Plant area P&T system was completed. The system consists of two extraction wells (299-W19-113 and 299-W19-114) and aboveground pipelines to convey extracted groundwater to the 200 West P&T for treatment. The system is designed to remediate the uranium, technetium-99, and high-concentration portion of the nitrate plume downgradient from the 216-U-1 and 216-U-2 Cribs. Additional wells (299-W19-115 and 299-W19-116) were installed in 2016 to monitor the uranium plume.
- The U Plant area P&T system began operating during September 2015. During 2016, the extraction wells operated at a combined average rate of 571 L/min (151 gpm), which was 101% of the nominal design rate of 568 L/min (150 gpm).
- During 2016, the U Plant area P&T system extracted 301 million L (80 million gal) of water, containing an estimated 9.9 kg of uranium; 27.5 g (0.47 Ci) of technetium-99; 48,800 kg of nitrate; and 24.4 kg of carbon tetrachloride from the aquifer.
- Capture zones for the U Plant area P&T system indicate that the system will capture about 60% of the areal extent of the uranium plume above 30 µg/L and about 70% of the plume above 300 µg/L. Two additional wells, 299-W19-123 and 299-W19-125, will be installed in 2017 with well 299-W19-125 planned as an extraction well. As data from operations and new monitoring wells become available, numerical modeling for system optimization will be performed to ensure that remediation objectives will be achieved with the current system; if not, alternatives to improve capture will be investigated.
- The U Plant P&T area UCL_{95} values calculated annually from 2008 to 2016 ranged between 160 and 320 µg/L for uranium; 1,710 and 18,820 pCi/L for technetium-99; and 270 and 1,220 mg/L for nitrate. Concentrations rebounded to higher levels for all three constituents after the second P&T system was shut down in 2011. For the third P&T system, started in 2015, it may take a number of years for the UCL_{95} to reflect progress in plume remediation because data for several years are used in the calculation.
- Injection wells for the iodine-129 plume hydraulic containment system began operating in late October 2015. Operation of these wells form a hydraulic barrier by increasing the water table elevation downgradient of the plume to slow its eastward migration.

- The iodine-129 plume hydraulic containment injection wells were designed to operate at nominal flow rates of 189 to 379 L/min (50 to 100 gpm) per well. During 2016, 299-E20-1 operated at an average rate of 173 L/min (45.8 gpm), 299-E20-2 operated at an average rate of 129 L/min (34.2 gpm), and 299-E11-1 operated at an average rate of 203 L/min (53.8 gpm).
- To design the P&T system for the southeast chromium plume, additional information is needed regarding plume extent. During 2016, three monitoring wells were constructed, improving definition of the plume. Seven additional wells are planned for drilling in 2017.
- MNA was evaluated statistically by calculating the one-sided UCL95 on the mean of the tritium and nitrate plume concentrations for the OU. Between 2008 and 2016, annual tritium and nitrate UCL95 values were still above cleanup levels. Tritium values ranged between 50,100 and 90,500 pCi/L, and nitrate values ranged between 93 and 130 mg/L.

4 200-ZP-1 Operable Unit Remedial Actions

This chapter discusses the remedial activities performed within the 200-ZP-1 OU during 2016, including activities associated with the 200 West P&T. The 200-ZP-1 remedy has four components: the 200 West groundwater P&T system, MNA, flow-path control, and ICs. The 200-ZP-1 OU addresses groundwater contaminant plumes beneath the northern two thirds of the 200 West Area. The 200 West P&T described in Chapter 2 is designed to remove carbon tetrachloride, total and hexavalent chromium, nitrate, technetium-99, TCE, low concentrations of iodine-129, and uranium from contaminated water using IX, anoxic and aerobic bioreactors, and air stripping. This chapter describes results of contaminant monitoring, hydraulic analyses, flow rates and volumes for the extraction and injection wells, and amount of contaminant removed from the aquifer. This information is used to assess progress toward achieving the RAOs and to asses remedy performance so operational improvements can be made, if needed. This chapter also addresses MNA.

The 200 West P&T is designed to capture and treat contaminated water and reduce the mass of COCs (Table 4-1) throughout the 200-ZP-1 OU by a minimum of 95% in 25 years. The 200 West P&T has been implemented in combination with MNA to achieve cleanup levels in Table 4-1 for all 200-ZP-1 COCs in 125 years. Tritium is also a COC in the 200-ZP-1 OU, but there is no cost-effective method for treating tritium in groundwater. However, due to the short half-life of tritium, concentrations will be reduced to below the cleanup level by natural radioactive decay within the same 125-year period. The final ROD for the 200-ZP-1 OU (EPA et al., 2008) provides the regulatory framework for remediation of the OU.

Table 4-1. Final Cleanup Levels for the 200-ZP-1 Groundwater OU

Contaminant of Concern	90th Percentile Concentration	MCL		Model Toxics Control Act Method B Cleanup Levels		Final Cleanup Level
		Federal	State	Noncarcinogens	Carcinogens at 10^{-5} Risk Level	
Carbon tetrachloride	2,900	5	5	5.6	3.4 [a]	3.4 [b]
Chromium (total)	130	100	100	24,000	—	100
Hexavalent chromium	203	— [c]	— [c]	48	—	48
Iodine-129	1.2	1	1	—	—	1
Nitrate [d] (as NO_3)	359,052	45,000	45,000	113,408	—	45,000
Nitrate [d] (as N)	81,050	10,000	10,000	25,600	—	10,000
Technetium-99	1,442	900	900	—	—	900
Trichloroethene	10.9	5	5	2.4	1 [a]	1 [b]
Tritium	36,200	20,000	20,000	—	—	20,000

Reference: EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington*.

Notes: Units are µg/L for nonradionuclides and pCi/L for radionuclides.

Federal MCL values are from 40 CFR 141, "National Primary Drinking Water Regulations," with iodine-129 and technetium-99 values from EPA 816-F-00-002, *Implementation Guidance for Radionuclides*.

State MCL values are from WAC 246-290, "Group A Public Water Supplies."

a. WAC 173-340-705, "Model Toxics Control Act—Cleanup," "Use of Method B," cleanup levels for carbon tetrachloride and trichloroethene are from the Cleanup Levels and Risk Calculations (CLARC) database table (Ecology, 2008).

b. DOE will clean up COCs for the 200-ZP-1 OU subject to WAC 173-340 (carbon tetrachloride and trichloroethene), so the excess lifetime cancer risk does not exceed 1×10^{-5} at the conclusion of the remedy.

c. There is no MCL specific to hexavalent chromium.

d. Nitrate may be expressed as total nitrate (NO_3) or as total nitrogen (N). The MCL for nitrate as NO_3 is 45,000 µg/L, and the same concentration expressed as N is 10,000 µg/L. (Note that EPA's drinking water regulations are published as 10,000 µg/L.)

— = not applicable MCL = maximum contaminant level

Soil vapor extraction was used as an interim action to remove vadose zone carbon tetrachloride in 1992 (Smith and Stanley, 1992, "Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume"). Finalized in September 2011 (EPA et al., 2011), the 200-PW-1 OU CERCLA ROD selected soil vapor extraction (SVE) as the final remedial action for vadose zone carbon tetrachloride contamination at these three waste sites.

During SVE operations, vapor-phase carbon tetrachloride was extracted through multiple vadose zone wells and adsorbed onto GAC before the treated, clean vapor was released to the atmosphere. Between 1992 and 2012 (the last year of SVE operation), 80,107 kg of carbon tetrachloride was removed from the vadose zone. This remedy was evaluated using the process outlined in PNNL-21843, *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance*, and DOE/RL-2014-18, *Path Forward For Future 200-PW-1 Operable Unit Soil Vapor Extraction Operations*. In November 2015, EPA concurred that the SVE remedy met the RAOs in the ROD and that SVE activities could be ended. EPA concurrence with the response action report (DOE/RL-2014-48, *Response Action Report for the 200-PW-1 Operable Unit Soil Vapor Extraction Remediation*) in 2016 closed out the SVE portion of the 200-PW-1 OU remedy in the ROD and initiated activities to terminate SVE operations and vadose zone monitoring.

Activities performed during 2016 included installing a new injection well to support the 200-ZP-1 OU flow-path control component, installing a monitoring well to track the 200 West P&T performance, and connecting and operating an additional 200-ZP-1 extraction well and three 200-DV-1 OU wells (Chapter 5).

4.1 Remedial System Operation

Operational performance of the 200 West P&T in support of the 200-ZP-1 OU remedial system operations is described in Chapter 2, which includes discussion of flow rates and data collected to monitor performance during 2016. Decisions regarding optimization and system performance (to meet RAOs) will be made based on an evaluation of the data against the DSs presented in the 200-ZP-1 PMP (DOE/RL-2009-115).

4.1.1 Overview of Remedial System

The extraction and injection well network is designed for hydraulic containment and recovery of contaminants associated with the 200-ZP-1 OU. Extracted groundwater is transferred for treatment through the 200 West P&T described in Chapter 2. The 200-ZP-1 extraction wells are 20 cm (8 in.) with screens above 30 m (98 ft) placed to within 3 m (9.8 ft) of the bottom. Extraction well screens in 200-ZP-1 OU target intervals with carbon tetrachloride concentrations above 100 µg/L. Well spacing was sufficient to capture contaminants at elevated concentrations throughout the aquifer underlying the 200-ZP-1 OU (DOE/RL-2010-13).

Some treated water from the 200 West P&T is injected to the northeast and east of the 200-ZP-1 OU extraction wells to reduce and reverse natural eastward hydraulic gradient in the aquifer and to minimize potential for groundwater in the aquifer to flow northward through Gable Gap toward the Columbia River (referred to in the ROD [EPA et al., 2008] and PMP [DOE/RL-2009-115] as flow-path control). Groundwater mounding in the aquifer slows the natural eastward flow and keeps the majority of the COC targeted area of COCs within the hydraulic capture zone of the extraction wells, also enabling natural attenuation to reduce contaminant concentrations beyond the capture zone. Injection wells installed in 200-ZP-1 to the west (i.e., upgradient of the 200-ZP-1 OU extraction wells) are used to recharge the aquifer and steepen hydraulic gradients to the east to accelerate the flushing of the most highly contaminated portions of the aquifer.

4.2 200-ZP-1 Hydraulic Monitoring

This section describes and interprets the data obtained from the hydraulic monitoring network implemented to evaluate conditions for 200-ZP-1 in CY 2016. The initial baseline data for the 200-ZP-1 OU, collected in 2012 prior to the startup of the 200 West P&T, will be used for comparison with 2016 data from 200-ZP-1

and in future years for understanding contaminant distribution and movement within the aquifer beneath the 200-ZP-1 OU. These data provide a technical basis for addressing three of the four components of the selected remedy to assess the remedy's success against the RAOs: P&T, MNA, and flow-path control. The fourth component (ICs) is addressed in DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*. Data are collected for the 200-ZP-1 OU COCs and uranium (200-UP-1 OU source), which is present in some wells in the monitoring network.

4.2.1 Hydraulic Monitoring Network

The hydraulic monitoring network for the 200-ZP-1 OU groundwater remedy comprises water levels obtained from the following sources:

- Monitoring wells using manual (depth-to-water) measurements
- Monitoring wells using data loggers equipped with transducers, with records stored on the data logger and retrieved using telemetry (referred to as the automated water level network [AWLN])
- Extraction and injection wells using transducers with records stored on the central treatment system supervisory control and data acquisition system and retrieved via a human/machine interface

When reviewing and interpreting water level data, flow rates recorded at each remedy extraction and injection well are also reviewed to provide an understanding of the probable cause(s) of changes in groundwater levels.

Groundwater level data obtained during 2016 comprise water levels obtained during synoptic water level campaigns, where water levels are obtained from a defined group of wells that cover a wide area throughout the OU and water levels obtained are from the AWLN, which comprises a smaller number of wells than is measured during synoptic surveys but that provide an essentially continuous record at those locations. The following subsections describe water level data obtained during 2016 and present depictions and interpretations of these data.

4.2.1.1 Synoptic Survey Data

The synoptic water level event in the 200 West Area occurred in March 2016 when water levels were obtained from over 100 monitoring wells in 200-ZP-1 and additional wells in the neighboring 200-UP-1 OU and 200 East Area. From 166 well locations in FY 2016 and during the synoptic event in March, 133 wells from the 200 West Area were used to prepare the depicted groundwater level maps.

4.2.1.2 Transducer Data

Throughout 2016, water levels were recorded using data loggers and transducers installed in approximately 30 monitoring wells throughout the 200-ZP-1 OU, plus additional wells instrumented with data loggers and pressure transducers as part of monitoring for the adjacent 200-UP-1 P&T remedies. In addition, water levels were recorded in the extraction and injection wells that were instrumented with data loggers and actively operating during 2016, which varied in number throughout the year.

4.2.2 Analysis of Hydraulic Monitoring Data

The 200 West P&T average total throughput ranged between about 3,610 L/min (954 gpm) in June and up to 8,191 L/min (2,164 gpm) in December. This total throughput combines groundwater extracted from the 200-ZP-1, 200-UP-1, 200-BP-5 OUs, and 200-DV-1 perched water.

Analyses of water level data presented in this report focus on conditions during December, representing sustained pumping rates that were achieved by the end of the year. Figure 4-1 depicts extraction and injection rates typical of operations during December 2016.

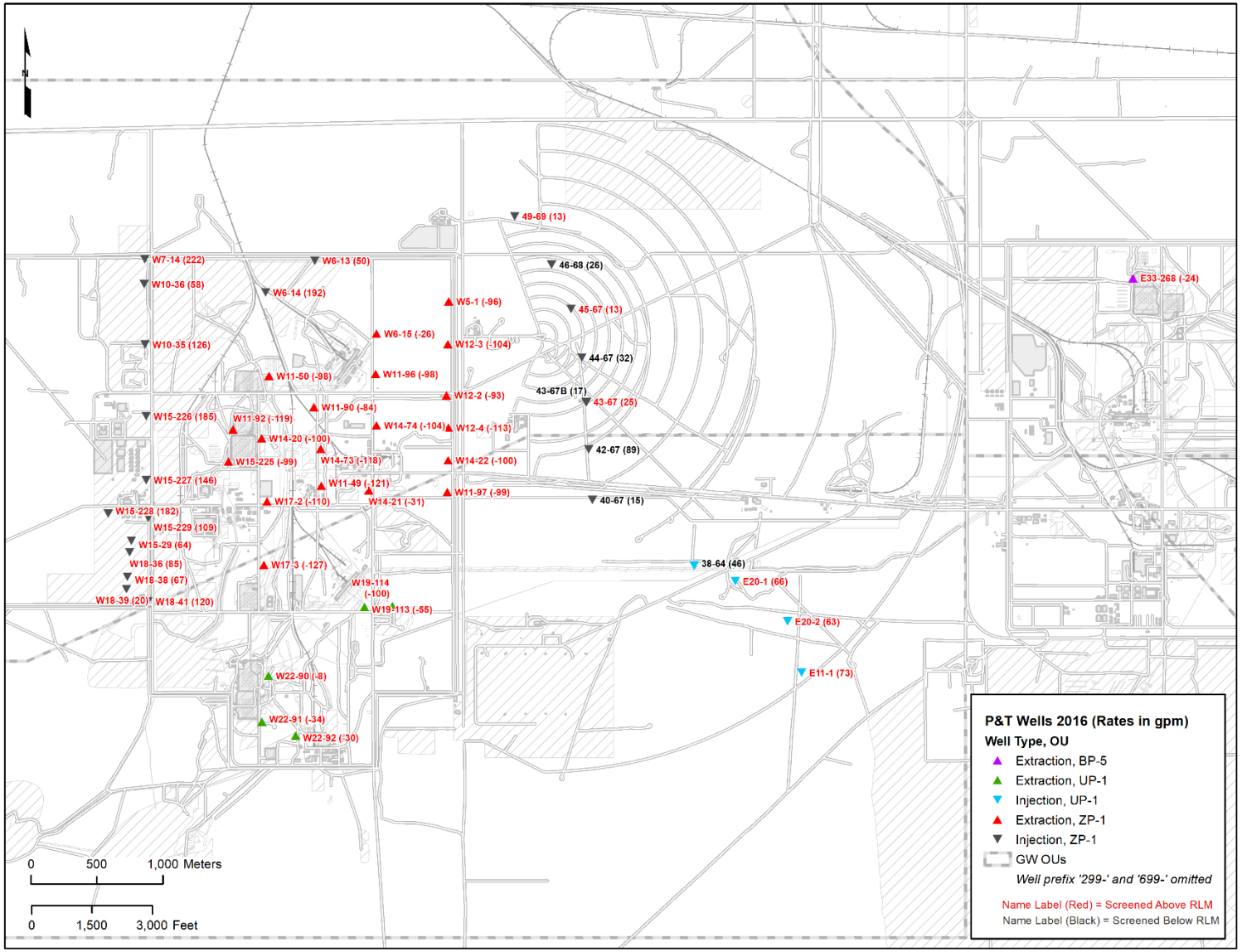
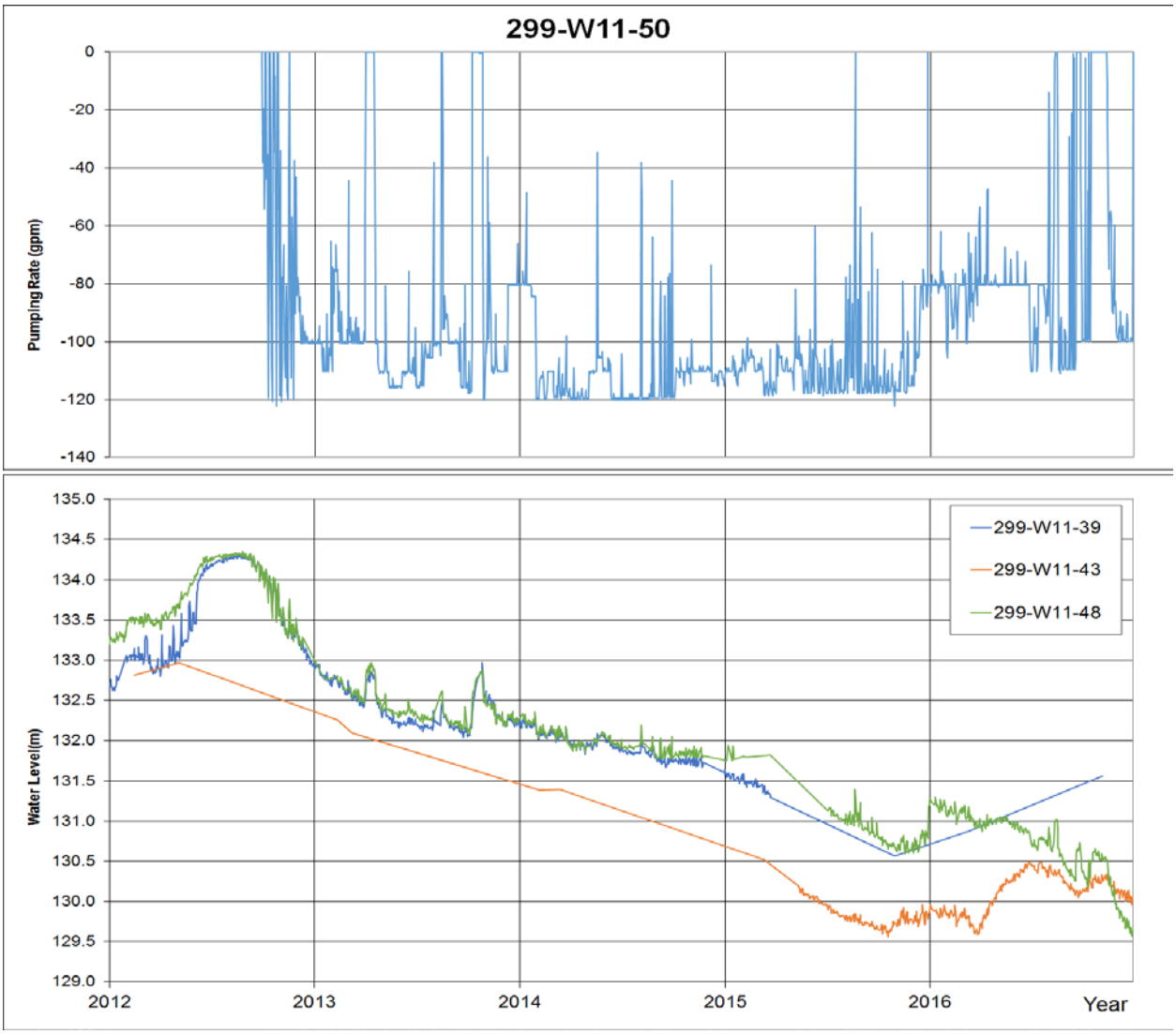


Figure 4-1. Groundwater Extraction and Injection Rates for the 200 West P&T, December 2016

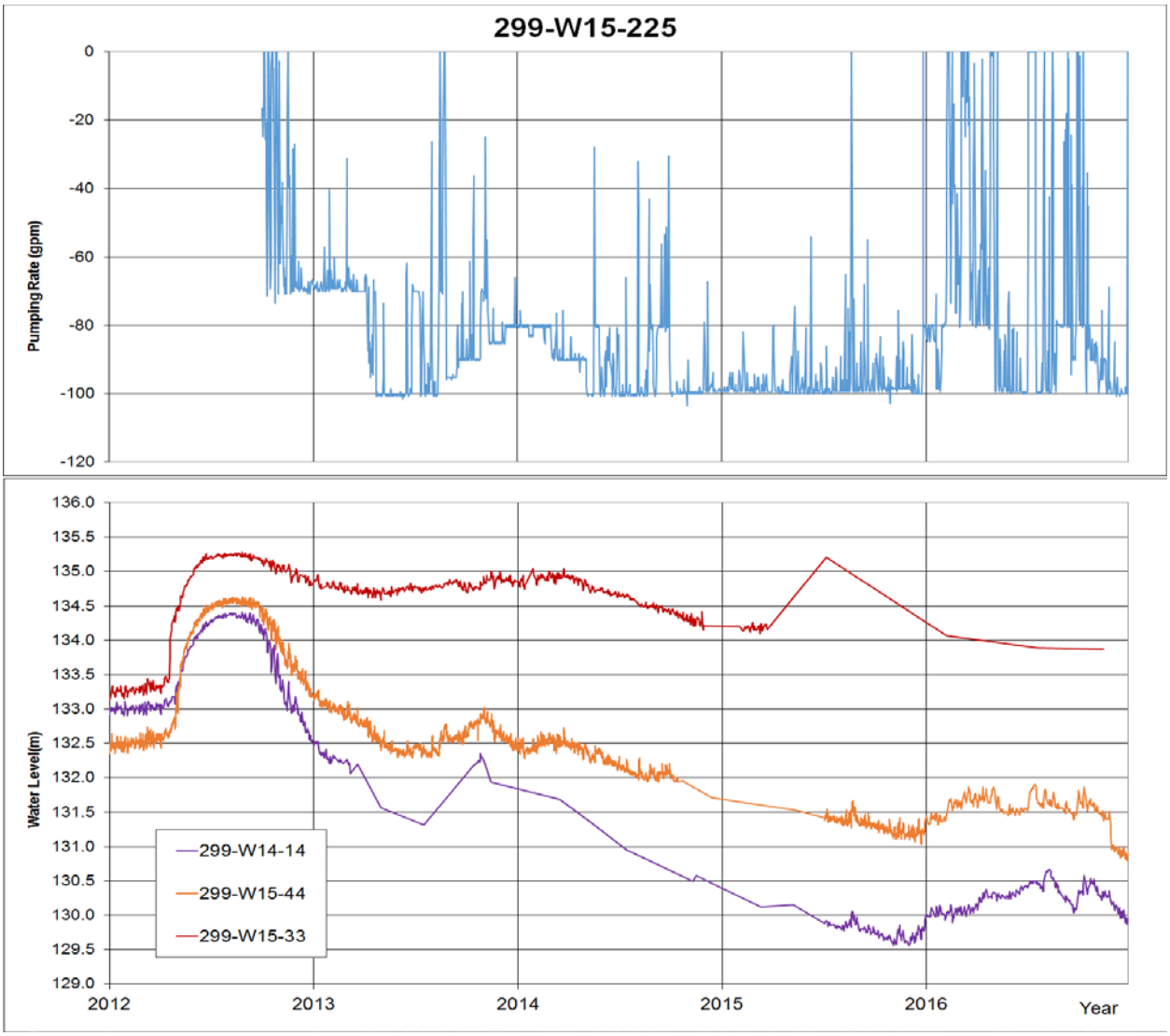
4.2.2.1 Evaluation of the Water Table

Extraction and injection rates for CY 2016 that were used for water level mapping and hydraulic containment analyses described in this subsection are depicted in Figures 2-4 through 2-7 in Chapter 2. Figures 4-2 through 4-4 present water level hydrographs for selected monitoring wells in the AWLN located near the 200-ZP-1 OU groundwater extraction wells. These figures illustrate the changes in groundwater elevations in response to changing pumping patterns throughout the 200-ZP-1 OU.



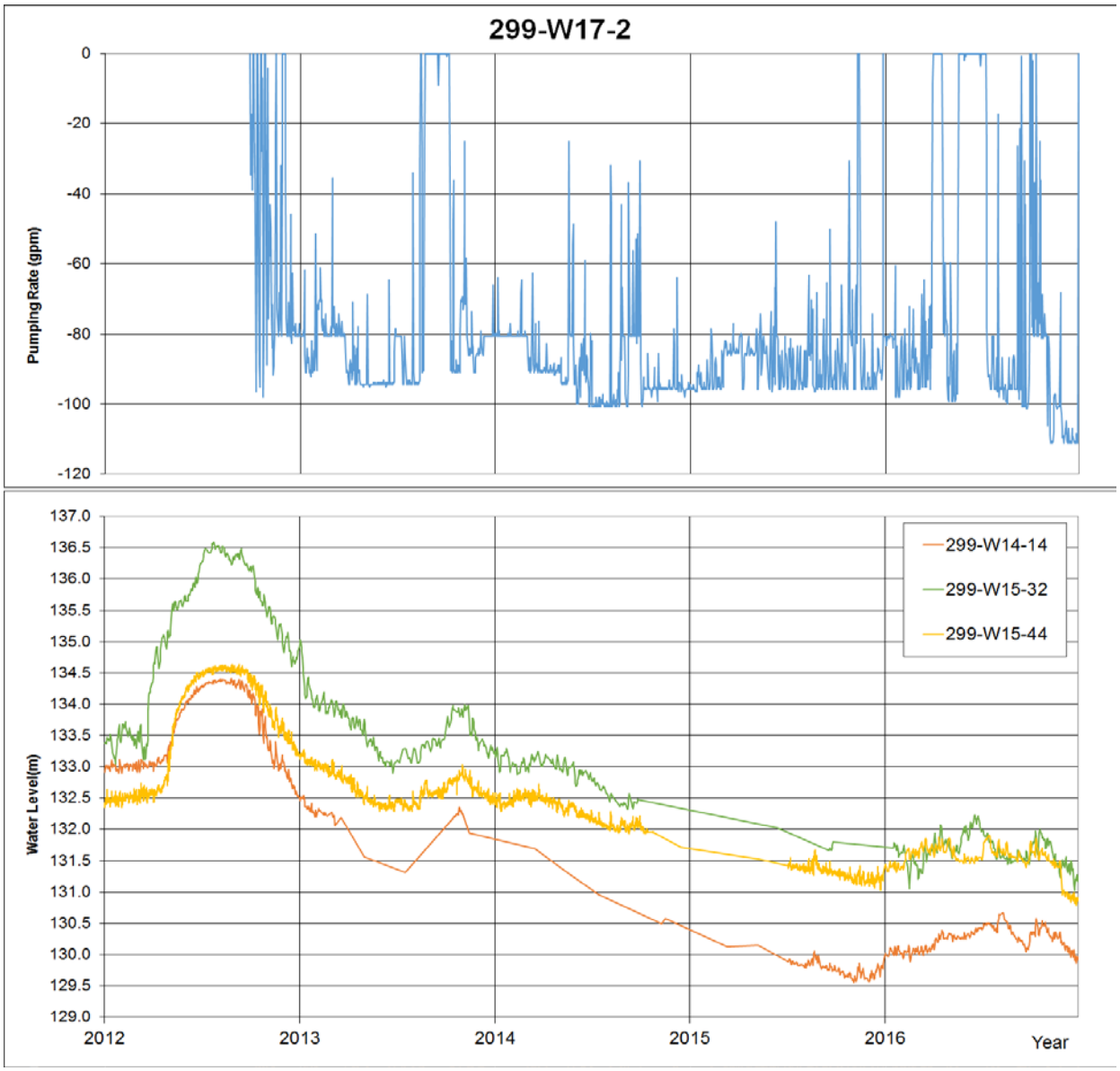
Note: Negative flow rate values indicate extraction out of the aquifer; positive flow rate values indicate injection into the aquifer.

Figure 4-2. Water Level Hydrographs for Selected Monitoring Wells Located near Groundwater Extraction Well 299-W11-50



Note: Negative flow rate values indicate extraction out of the aquifer; positive flow rate values indicate injection into the aquifer.

Figure 4-3. Water Level Hydrographs for Selected Monitoring Wells Located near Groundwater Extraction Well 299-W15-225



Note: Negative flow rate values indicate extraction out of the aquifer; positive flow rate values indicate injection into the aquifer.

Figure 4-4. Water Level Hydrographs for Selected Monitoring Wells Located near Groundwater Extraction Well 299-W17-2

Groundwater levels were evaluated in two dimensions by interpolating water level data obtained during December 2016. The difference between the interpolated water levels obtained using data from December 2016 and those obtained during June 2012 (prior to startup of the final 200-ZP-1 P&T remedy) illustrates the general pattern of impacts to groundwater levels of extraction and reinjection since the 200-ZP-1, and, to a lesser extent, the neighboring 200-UP-1, P&T remedy commenced operation. Groundwater elevation maps were constructed using the universal kriging technique described in SGW-42305 with a combination of manual water level data, AWLN data, and contemporaneous groundwater extraction and injection rates at operating P&T remedy wells.

Figure 4-5 depicts groundwater elevation contours computed using water level mapping. The first set of contours (Figure 4-5, inset a) depicts the mapped water table during June 2012, when no P&T remedy was operating in the 200 West Area (DOE/RL-2013-14, provide details on the original preparation of these contours). The second set of contours (Figure 4-5, inset b) depicts the mapped water table during December 2016 with the 200 West P&T and 200-UP-1 remedies operating in the 200 West Area. Figure 4-5 was prepared by interpolating water level data obtained from wells screened above the RLM unit (i.e., the unconfined aquifer) and incorporating groundwater extraction and injection that occurs above the RLM within one kriging trend (drift) term (SGW-42305). Comparison of Figure 4-5 inset a with inset b identifies focused areas of groundwater mounding in response to injection and drawdown in response to extraction at wells screened partially or entirely above the RLM. Because the majority of groundwater extraction occurs above the RLM, drawdown and mounding are clearly reflected in the measured water level data and elevation contours. Figure 4-5 (inset b) shows a well-defined area of convergent hydraulic gradients centered on the extraction wells.

Figure 4-6 presents two depictions of changes in groundwater levels as computed using the water level mapping method for data above the RLM between June 2012 and December 2016. The groundwater table in the Central Plateau is still decreasing in many areas as a result of the cessation of historical operational discharges of water to the subsurface. In 2014, the rate of decline was recently estimated to be about 0.22 to 0.27 m/yr (0.72 to 0.89 ft/yr). To accommodate this background decline of water levels that is not due to P&T remediation, Figure 4-6 (inset a) presents the simple difference between the June 2012 and December 2016 water level contours (i.e., unadjusted change), while Figure 4-6 (inset b) presents the difference between the June 2012 and December 2016 water level contours plus the estimated area-wide head change of about 0.875 m (2.87 ft) from June 2012 to December 2016 due to the cessation of historical operational discharges (i.e., adjusted change). Thus, Figure 4-6 (inset b) approximates the change in groundwater levels that is due solely to the operation of the P&T systems that are operating in the 200 West Area.

As was evident by comparing water level maps prior to and during operation of the two P&T remedies, focused areas of drawdown and mounding occur near extraction and injection wells, respectively. Near the 200-ZP-1 OU groundwater extraction wells that pump primarily above the RLM, a large area exhibits drawdown that exceeds 1 m (3.3 ft). A distinct region of the aquifer exhibiting mounding that exceeds 1 m (3.3 ft) is focused around the injection wells screened above the RLM on the west side of the 200-ZP-1 OU. A similar region of higher water levels is expected around the injection wells screened beneath the RLM on the east side of the 200-ZP-1 OU; however, this is not depicted in Figure 4-6, which only reflects changes in groundwater levels above the RLM.

Figure 4-7 depicts the estimated extent of hydraulic containment developed by groundwater extraction and reinjection at the 200 West P&T during December 2016, as determined through groundwater elevation mapping above the RLM. The estimate of hydraulic capture is based on particle tracking using the water level surfaces depicted in Figure 4-5 (inset b) and using the techniques detailed in SGW-42305. Figure 4-7 illustrates the combined extent of hydraulic containment rather than the extent of containment developed by individual wells, because the water level mapping technique does not explicitly conserve the flows to and from individual extraction and injection wells, respectively (SGW-42305). The extent of hydraulic containment depicted in Figure 4-7 is smaller than that which will ultimately be developed by the final remedy operating at design rate of 7,575 L/min (2,000 gpm).

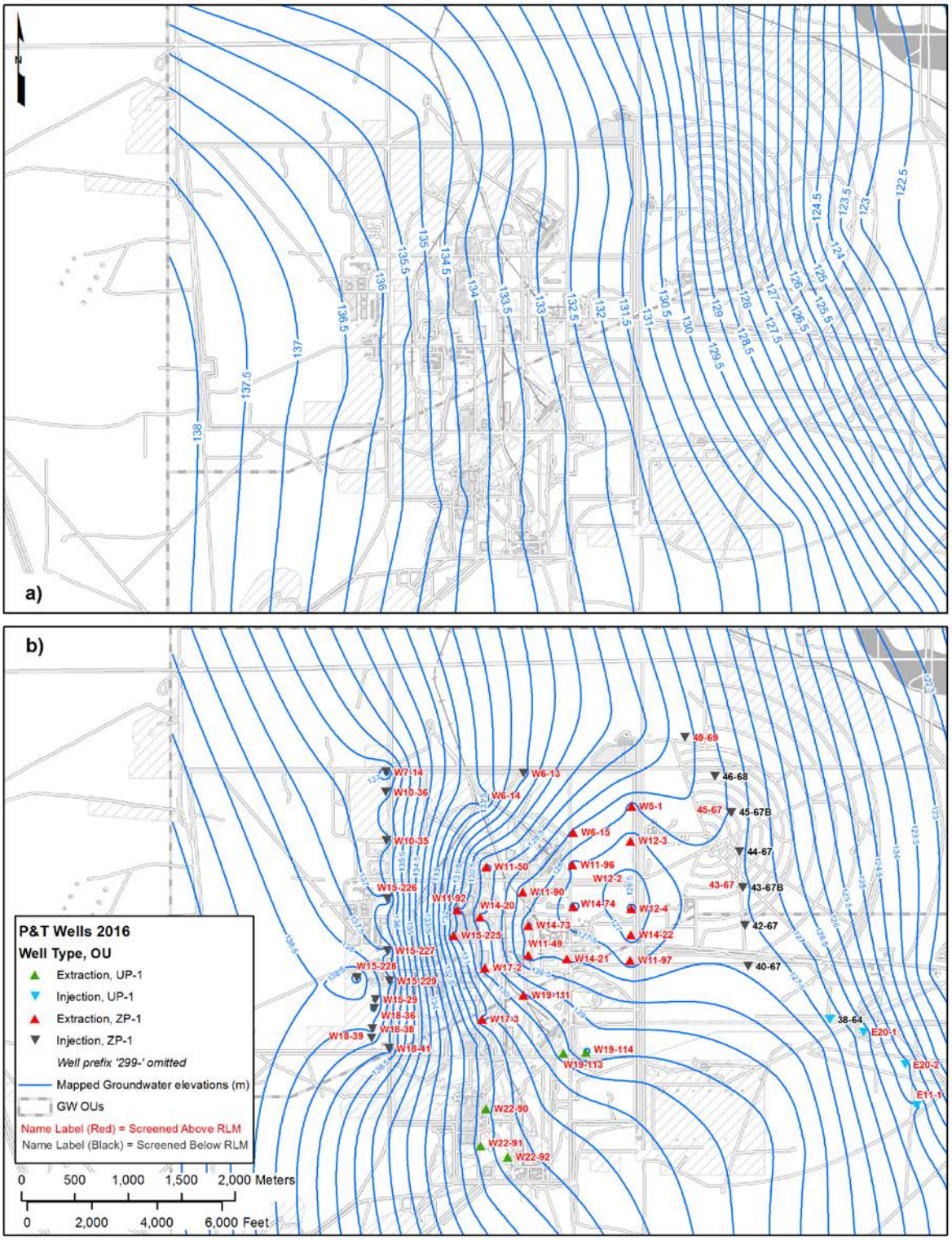


Figure 4-5. Groundwater Elevation Contours Computed Using Water Level Mapping: (a) above the RLM during June 2012; (b) above the RLM during December 2016

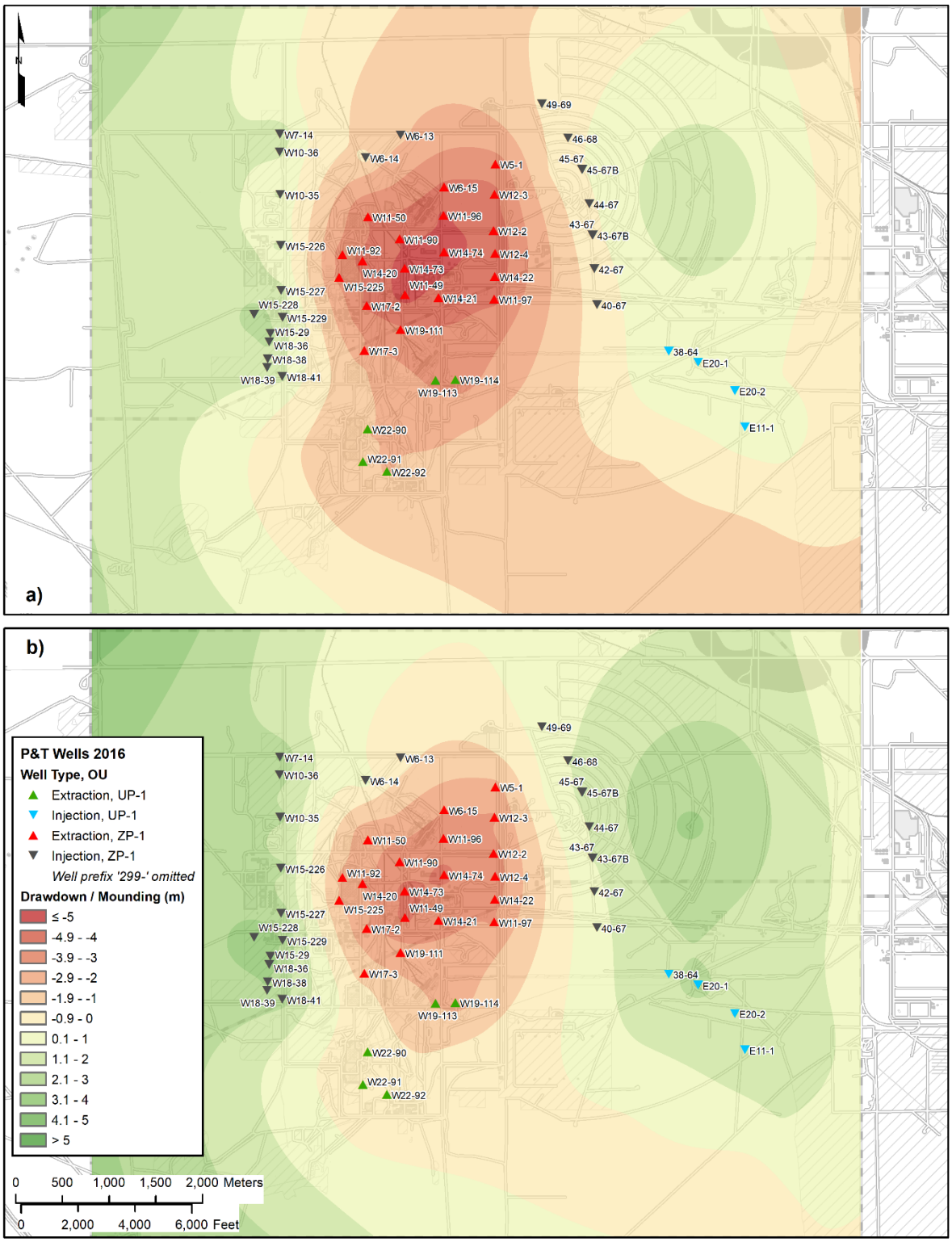


Figure 4-6. Drawdown and Mounding Computed Using Water Level Mapping above the RLM between June 2012 and December 2016: (a) Unadjusted; (b) Adjusted Calculation

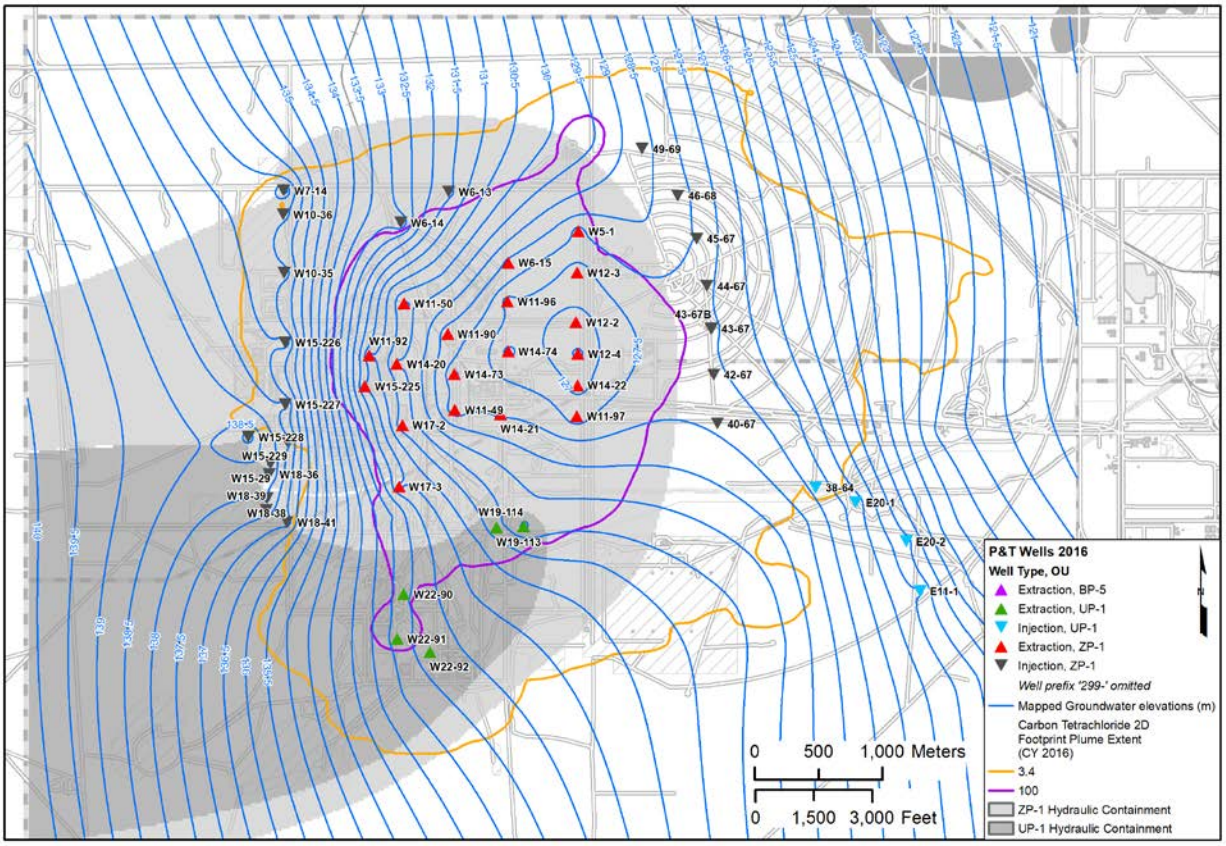


Figure 4-7. Extent of Hydraulic Containment Computed for December 2016 Using Water Level Mapping above the RLM

4.2.2.2 Sources of Uncertainty in Mapped Water Levels and Hydraulic Containment

The water level contour maps are constructed using a technique that incorporates the effects of drawdown and mounding due to groundwater extraction and reinjection (SGW-42305). The resulting contour maps represent the values of water levels measured at each well and provide a plausible interpretation of groundwater levels and hydraulic gradients between measured locations. However, the accuracy of the contours is influenced by the following factors:

- Accuracy of the measured (or recorded) water levels
- Number and distribution of monitoring locations
- Relationship between the open interval of the monitoring wells and those of the extraction and injection wells
- Presence, continuity, and hydraulic properties of the RLM
- Degree of adherence to, or violation of, assumptions that underlie the mapping method (as outlined in SGW-42305)

The unconfined aquifer in most of the 200 West Area is underlain by the RLM, which acts in most areas throughout the 200-ZP-1 OU as a locally confining unit. However, this unit is absent in the northeastern portion of the 200 West Area, so the unconfined aquifer extends to the top of the basalt.

These potential sources of error mean that the contour maps only approximate actual conditions. The water level and hydraulic containment maps are interpreted as reasonable approximations that provide value when interpreting the likely directions and rates of groundwater movement and the likely extents of convergent hydraulic gradients that are consistent with the interpretation of hydraulic containment. Water level and hydraulic containment depictions that are computed using the Central Plateau Groundwater Model (CPGWM; CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 3.3*) are presented in later subsections for comparison with the interpolated water level and hydraulic containment maps.

4.2.2.3 Impacts to the Remedy from Changing Groundwater Elevations

Groundwater elevation changes computed from the measured water level data are consistent with expectations based upon the 200-ZP-1 OU remedy design, as described in DOE/RL-2008-78. This section considers two potential impacts to the remedy from changing groundwater elevations:

1. Impacts to the monitoring network
2. Impacts to the efficacy of groundwater extraction (and reinjection) and, therefore, on hydraulic containment and contaminant mass recovery

As noted in SGW-50907, *Predicted Impact of Future Water-Level Declines on Groundwater Well Longevity within the 200 West Area, Hanford Site*, water level declines due to a combination of background regional decline plus groundwater extraction associated with remediation will cause some monitoring wells to go dry. This will prevent groundwater samples and water levels from being obtained at those locations and is expected to be most pronounced in areas adjacent to extraction wells.

SGW-50907 predicted 29 wells would become sample dry (i.e., possess less than 0.9 m [3 ft] of water above the bottom of the screened interval) soon after the startup of 200 West P&T (i.e., during CY 2012 and CY 2013). During CY 2016, the remaining wells that had not yet gone sample dry are as follows:

- 299-W15-3
- 299-W18-21
- 299-19-35
- 299-W6-12
- 299-W7-4
- 699-32-77
- 699-45-69A
- 699-48-77A
- 699-48-77D
- 699-50-59

In some cases, the status of a monitoring well is unknown for logistical reasons. For example, SGW-50907 predicted that 299-W15-3 would become sample dry during 2012, but this well is located inside a tank farm and has been inaccessible for routine sampling since 2009. As projected in SGW-50907, some wells may recover over time due to nearby reinjection of water treated at the 200 West P&T. For example, well 299-W8-1, which was sample dry during CY 2012, now contains sufficient water for sampling.

Declines in groundwater levels do have the potential to compromise the ability for an extraction well to recover contaminated groundwater through reduction in capacity. The extraction wells installed as part of the 200 West P&T were constructed with long, open intervals to provide high capacity and mitigate impacts to well performance from changing groundwater elevations. In most cases, the drawdown expected in the aquifer adjacent to each extraction well is a few meters, while the length of the open interval for most extraction wells is tens of meters long. During 2016, no notable impacts to extraction well performance were found as a result of declining water levels. However, the likelihood for declining extraction well performance as a result of water level declines and other factors (e.g., such as well screen or filter pack fouling) may increase over time as groundwater elevations continue to decline.

The effects of water level declines can be mitigated by rerouting a greater proportion of the treated water to be injected on the upgradient (west) side of the extraction wells whereas the potential effects of well fouling can be mitigated through testing, maintenance, and re-development of extraction wells as part of the operations and maintenance program.

4.3 200-ZP-1 Contaminant Monitoring

During 2016, the 200-ZP-1 monitoring well network (consisting of 48 monitoring wells) was sampled for carbon tetrachloride, nitrate, and TCE. As described in DOE/RL-2009-115, wells within and on the periphery of contaminant plumes were sampled in 2016 for the remaining COCs (total chromium, hexavalent chromium, iodine-129, technetium-99, and tritium). Sample data in 2016 from most monitoring wells and extraction wells indicated that COC concentrations are declining. Exceptions include those monitoring wells in close proximity to extraction wells which are pulling contamination in from the surrounding area. Additionally, an analysis of the data from both monitoring and extraction wells indicates that the current focus area of hydraulic containment and mass recovery is in the core area of the 200-ZP-1 OU groundwater extraction wells, and the region defined by the 100 µg/L carbon tetrachloride contour was almost entirely contained by pumping in the 200 West Area as of 2016.

DOE will monitor contaminants in groundwater over the lifetime of the remedial action to evaluate performance and optimize effectiveness (DOE/RL-2009-115).

4.3.1 Contaminant Monitoring Network and Parameters

According to the 200-ZP-1 ROD (EPA et al., 2008), contaminant distributions in groundwater in the 200-ZP-1 OU (Figures 4-8 through 4-30) are represented by three categories:

- High-concentration zone close to ponds, cribs, and trenches that were used to dispose liquid wastes. Data do not indicate the presence of significant dense, nonaqueous-phase liquid in groundwater acting as a continuing source.
- Larger dispersed or low concentration zone that has migrated from the discharge locations or overlies the high-concentration zone. This less contaminated groundwater can occur above the high-concentration zone where large quantities of lower concentration effluent were discharged during or after the high-concentration waste discharges.
- Area of technetium-99 contamination near WMA T and WMA TX-TY. The results from depth-discrete groundwater sampling in the newly installed wells in these areas show that the peak concentration of technetium-99 is typically found within the upper 15 m (50 ft) of the aquifer.
- The PMP for the 200-ZP-1 OU (DOE/RL-2009-115) describes the monitoring well selection process and selects a well network to monitor and assess the success of the remedy. The PMP also describes the key DS questions in the data quality objective process for the 200 West P&T (DOE/RL-2009-115).

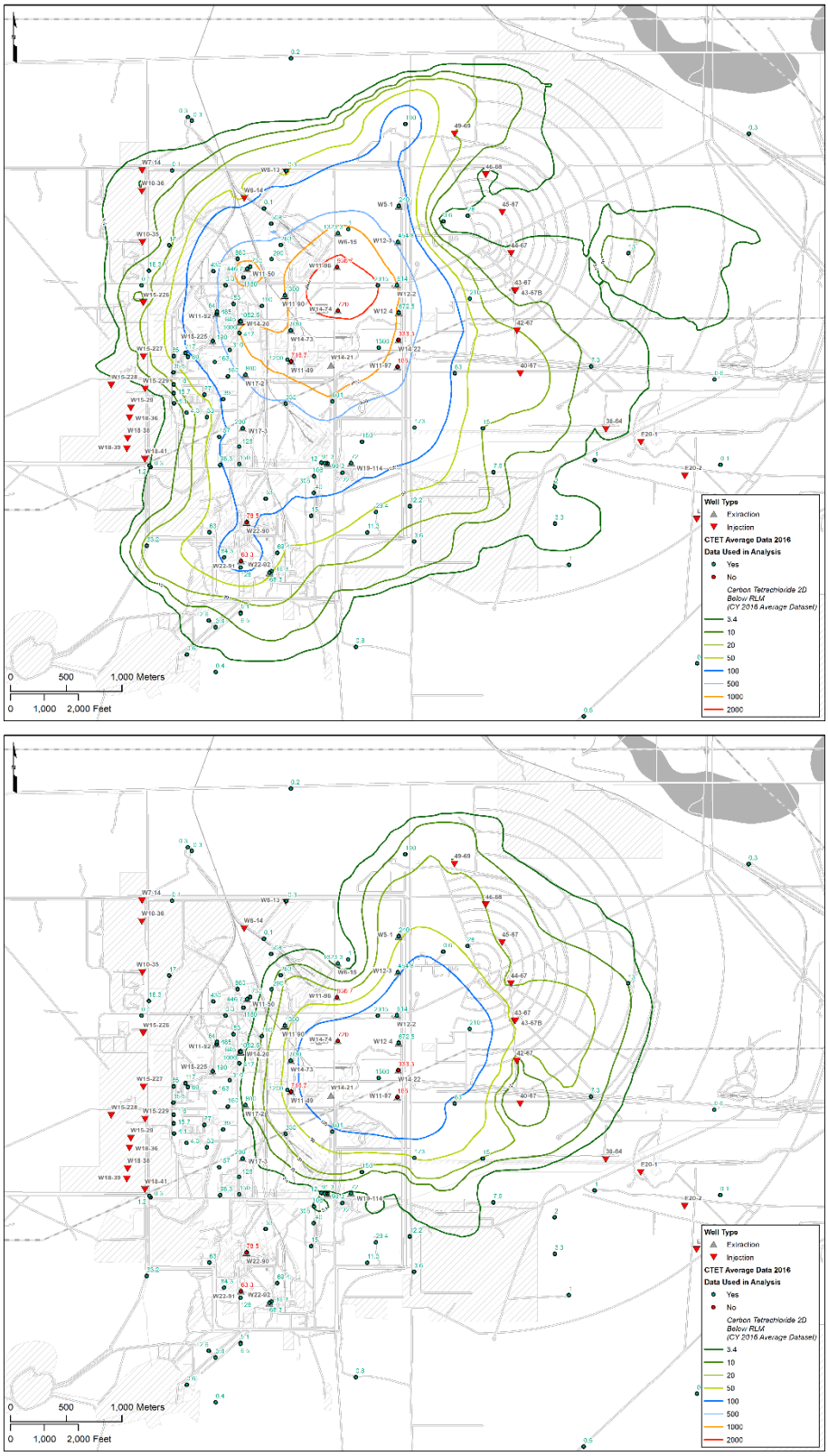


Figure 4-8. Contaminant Plume Map for Carbon Tetrachloride, 2016
(a) Above the RLM and (b) Below the RLM

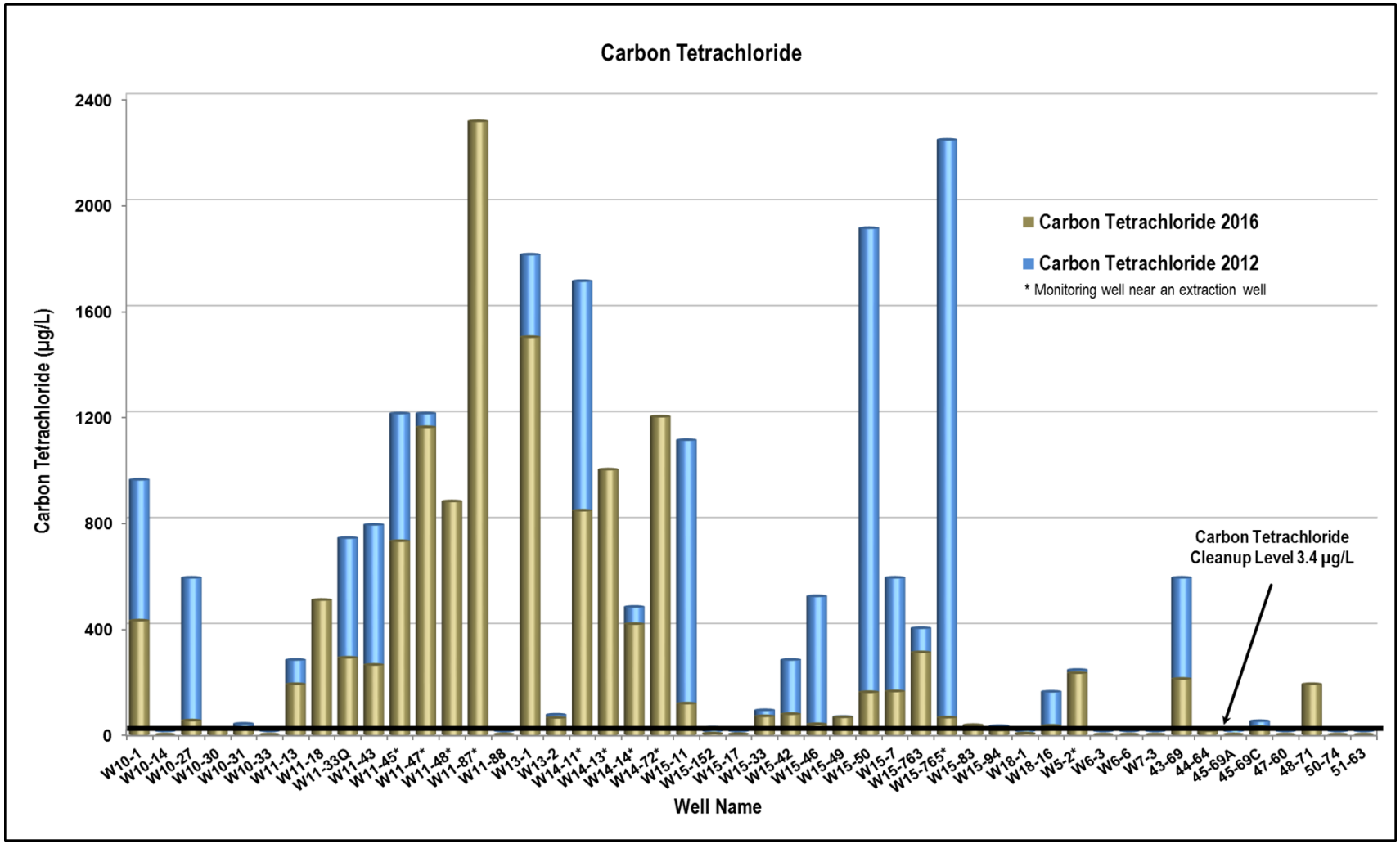


Figure 4-9. Comparison of Carbon Tetrachloride Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Graph

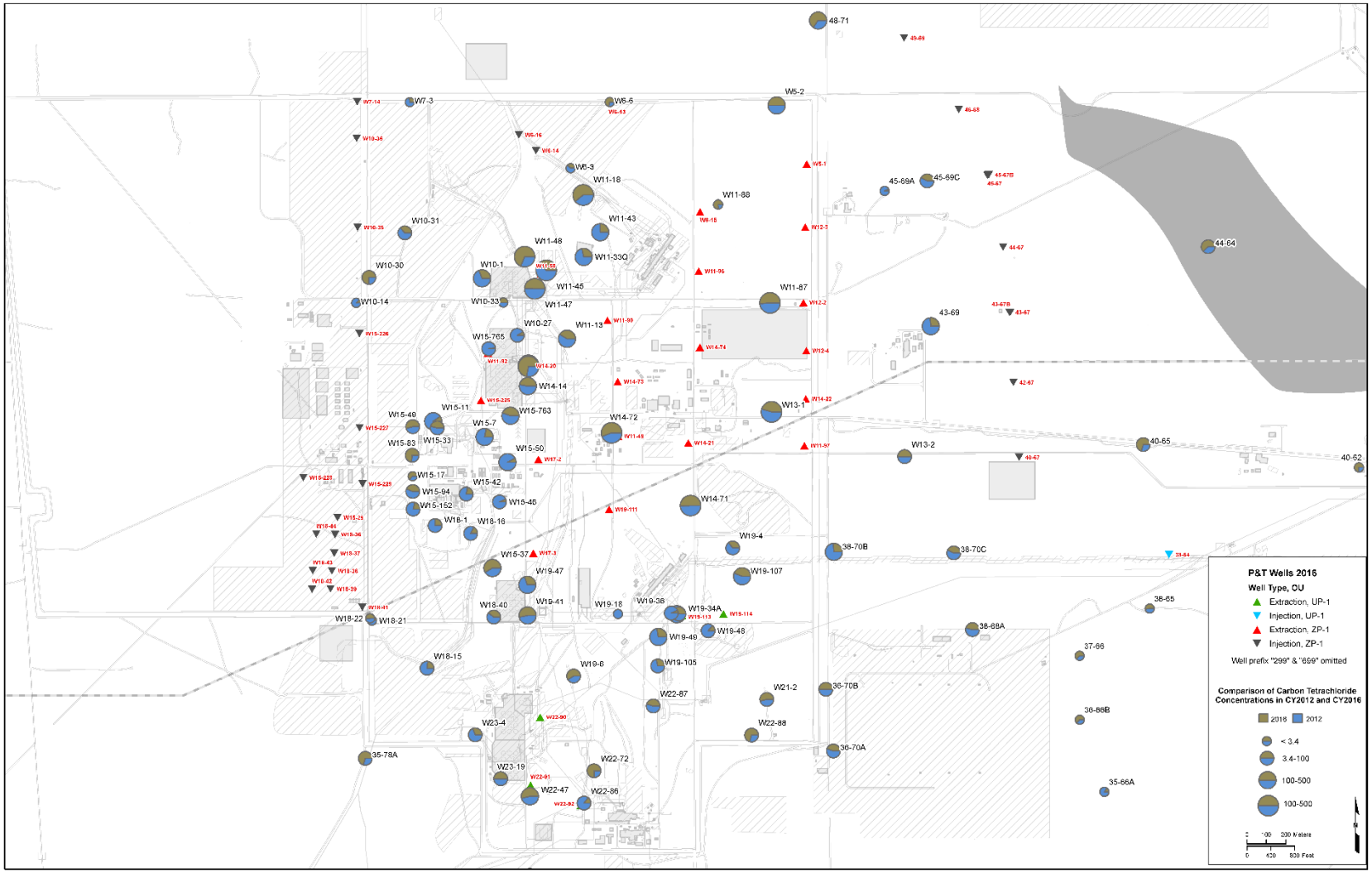


Figure 4-10. Comparison of Carbon Tetrachloride Concentrations in 200-ZP-1 and 200-UP-1 OU Monitoring Wells in 2012 and 2016: Map

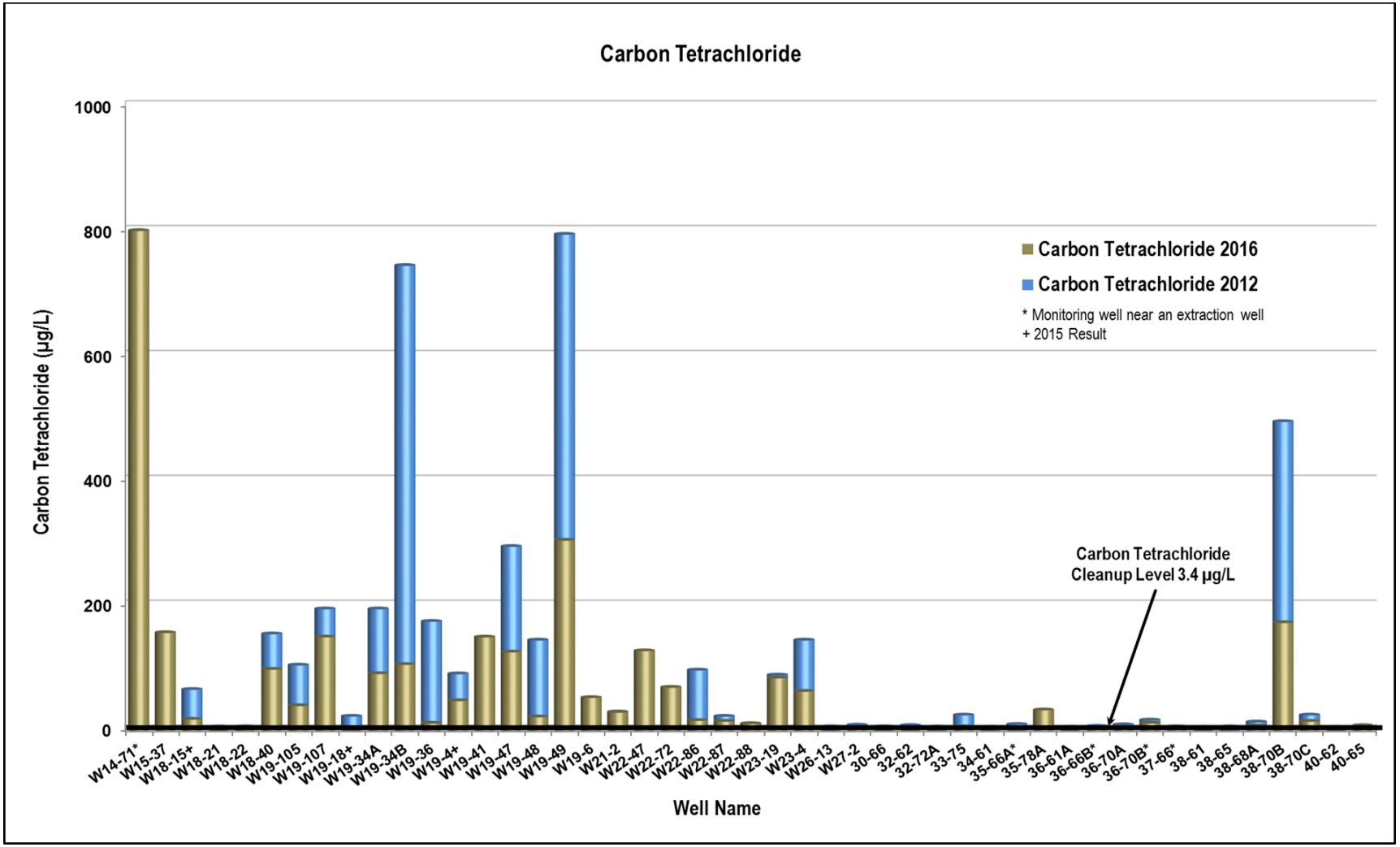


Figure 4-11. Comparison of Carbon Tetrachloride Concentrations in 200-UP-1 OU Monitoring Wells in 2012 and 2016

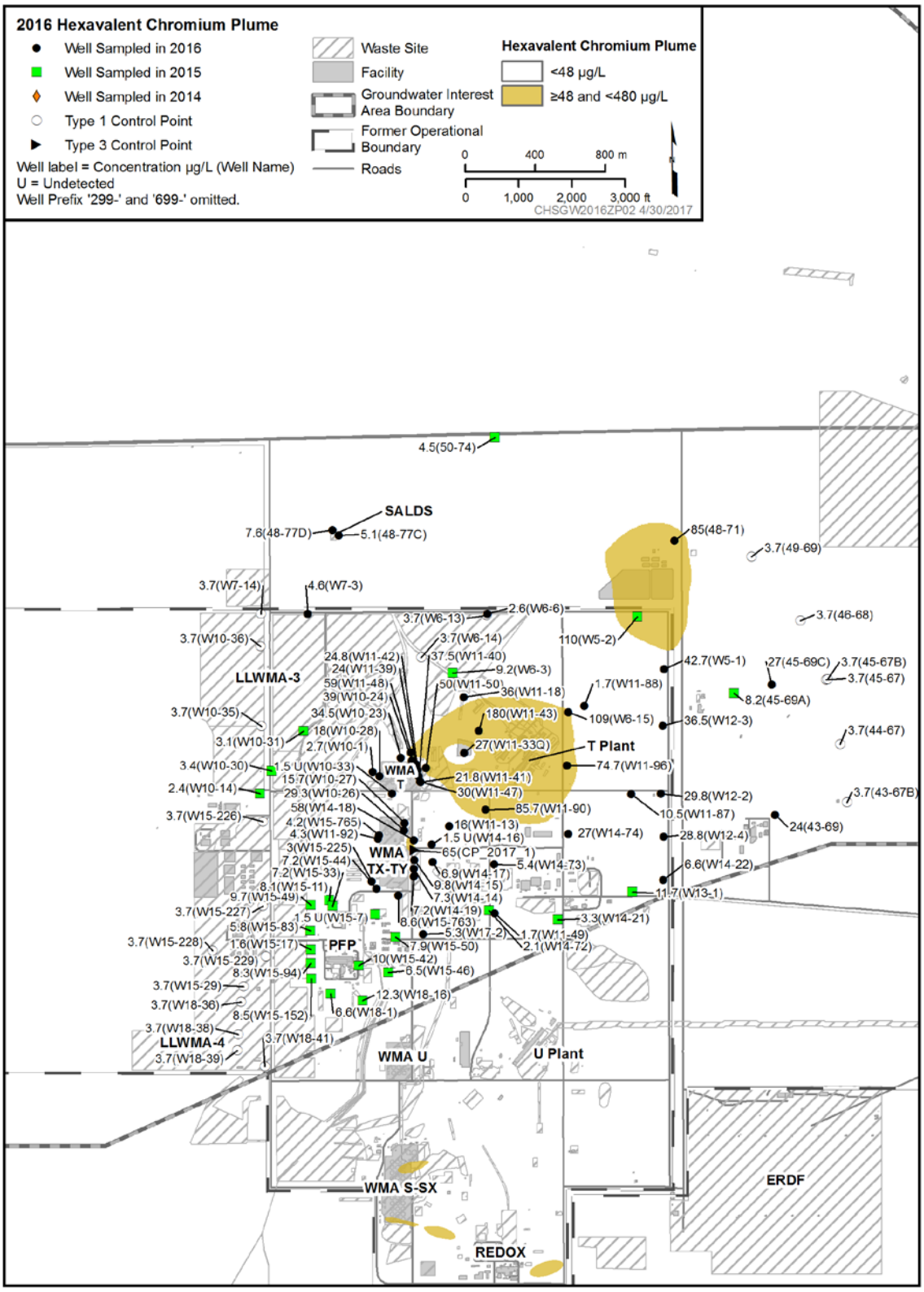


Figure 4-12. Contaminant Plume Map for Dissolved Chromium, 2016

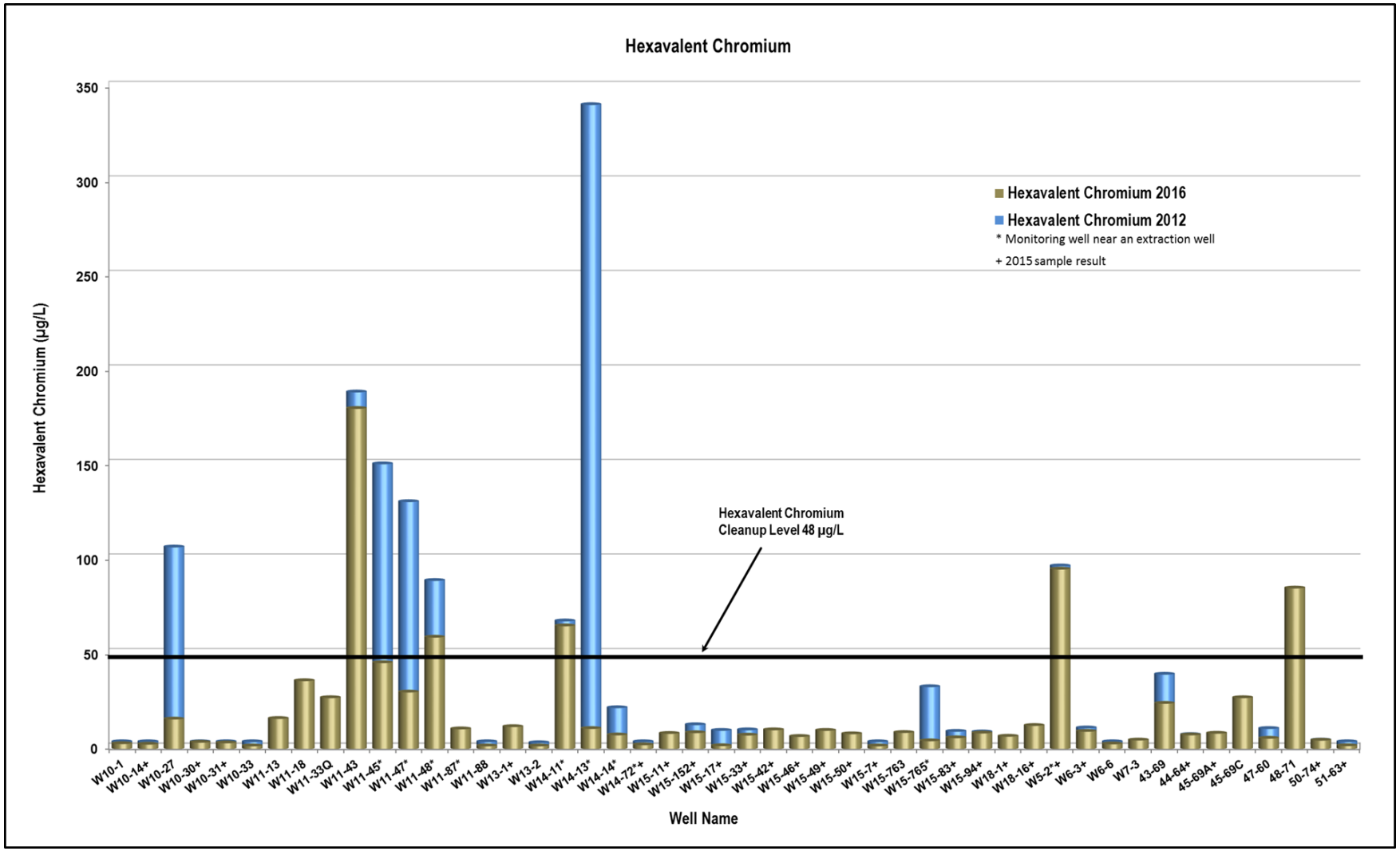


Figure 4-13. Comparison of Dissolved Chromium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Graph

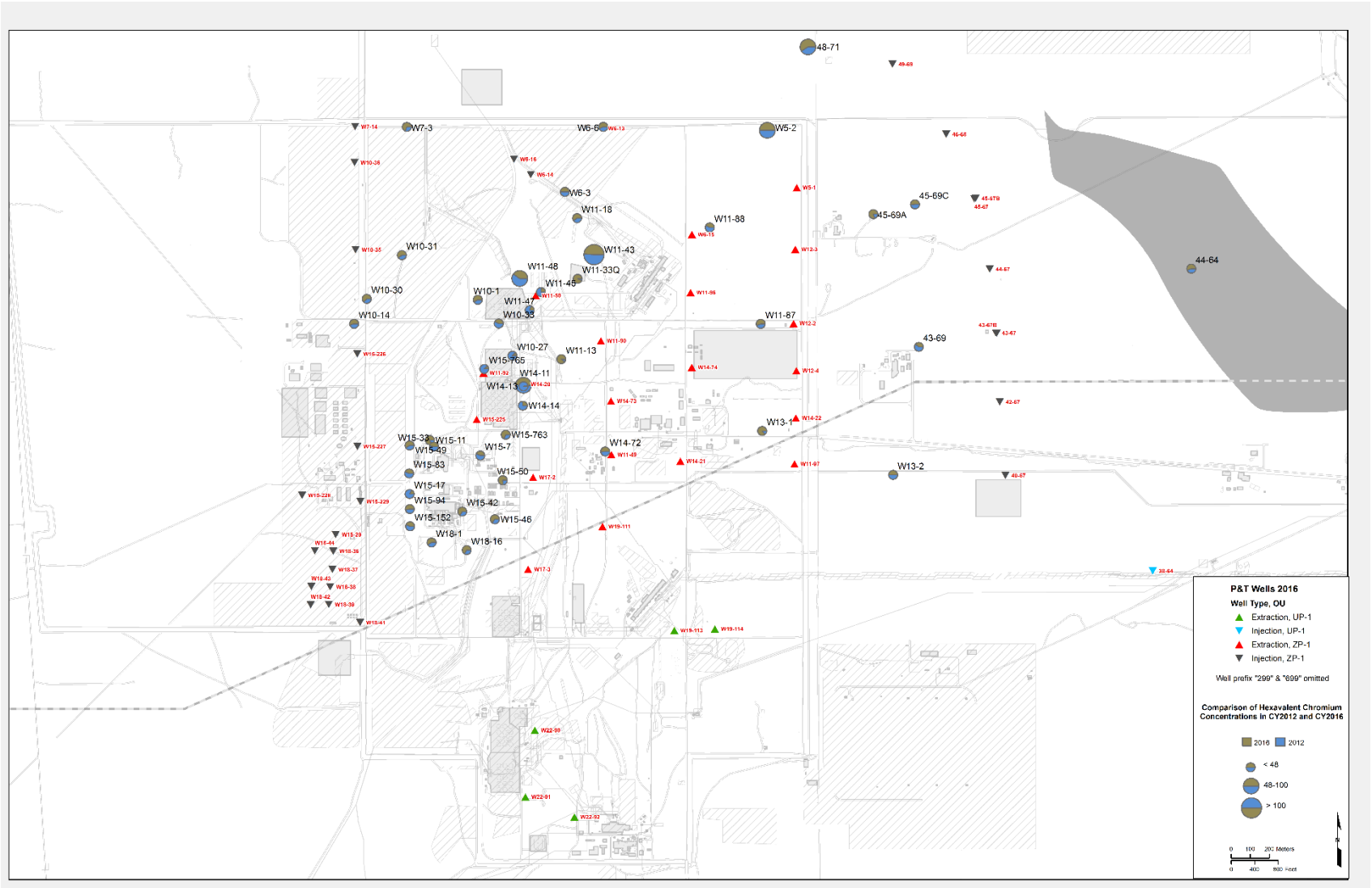


Figure 4-14. Comparison of Dissolved Chromium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Map

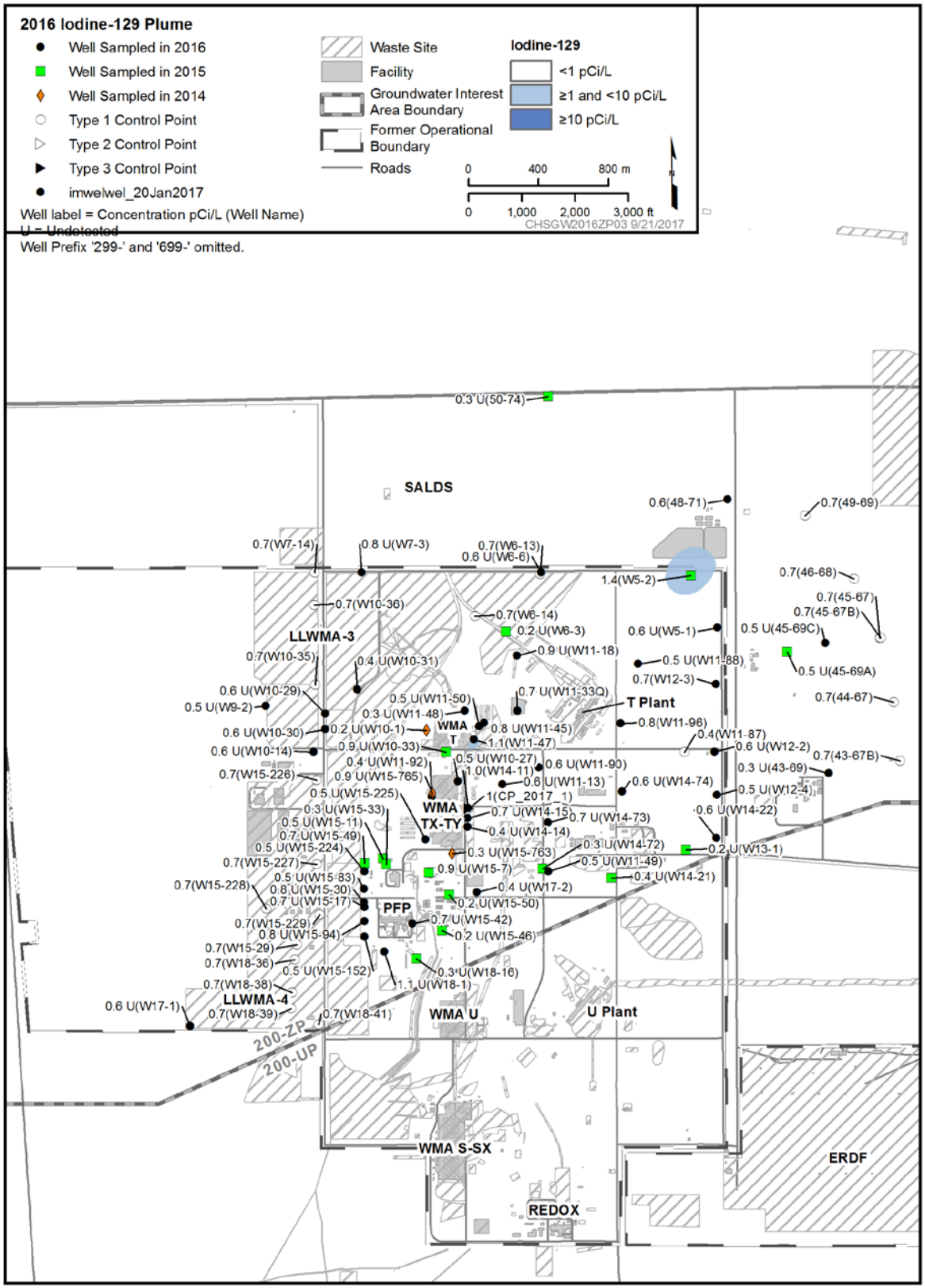


Figure 4-15. Contaminant Plume Map for Iodine-129, 2016

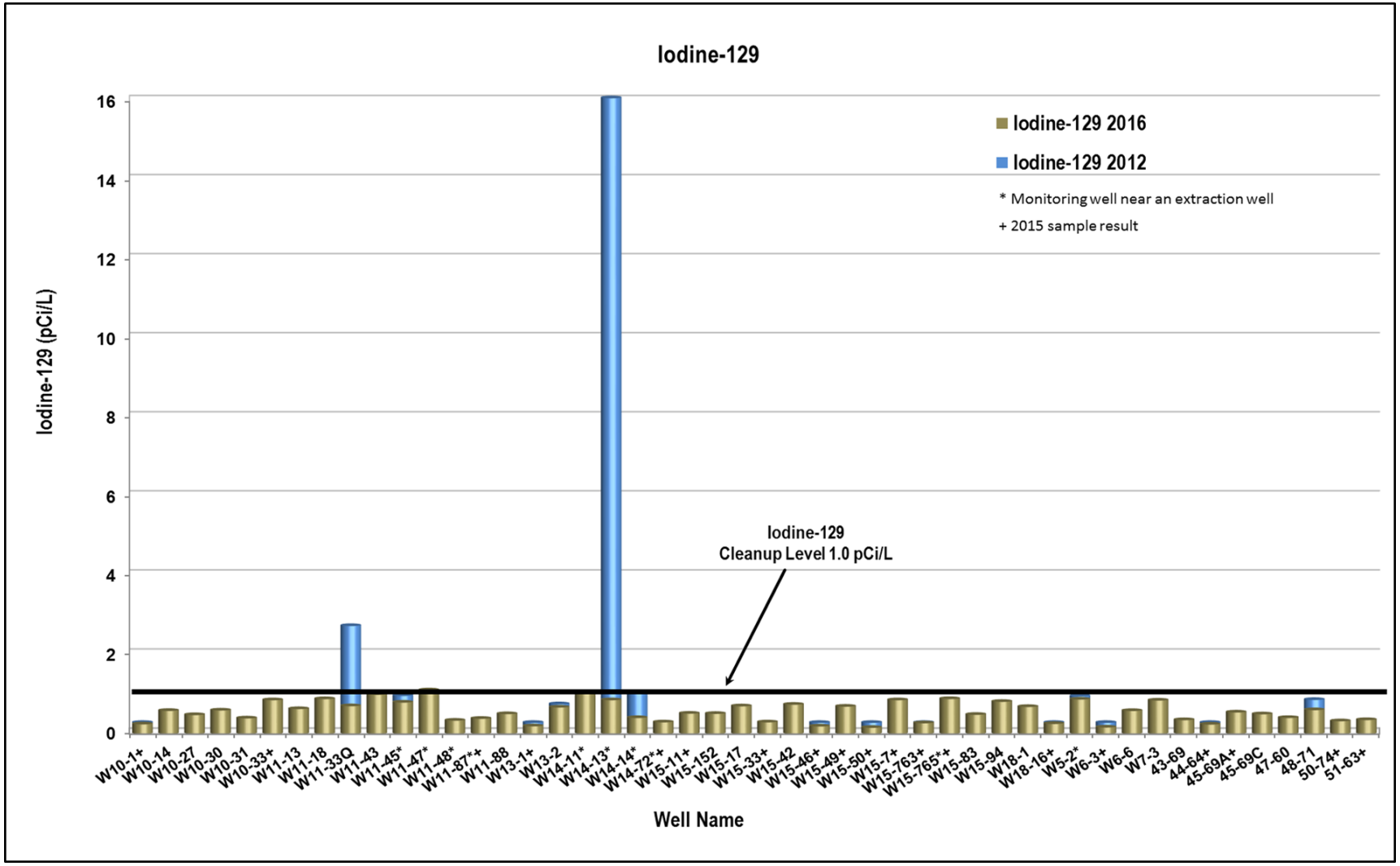


Figure 4-16. Comparison of Iodine-129 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Graph

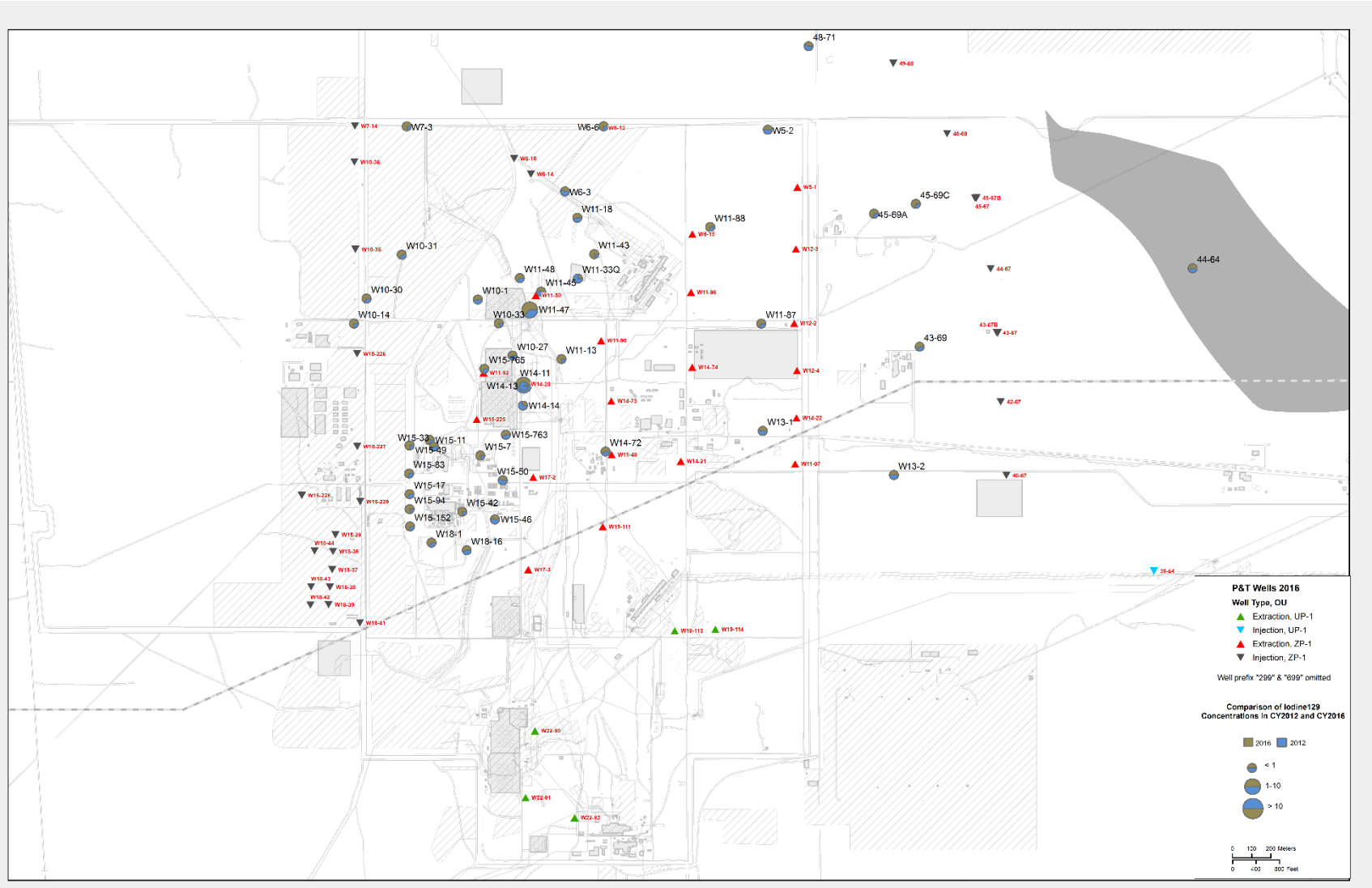


Figure 4-17. Comparison of Iodine 129 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Map

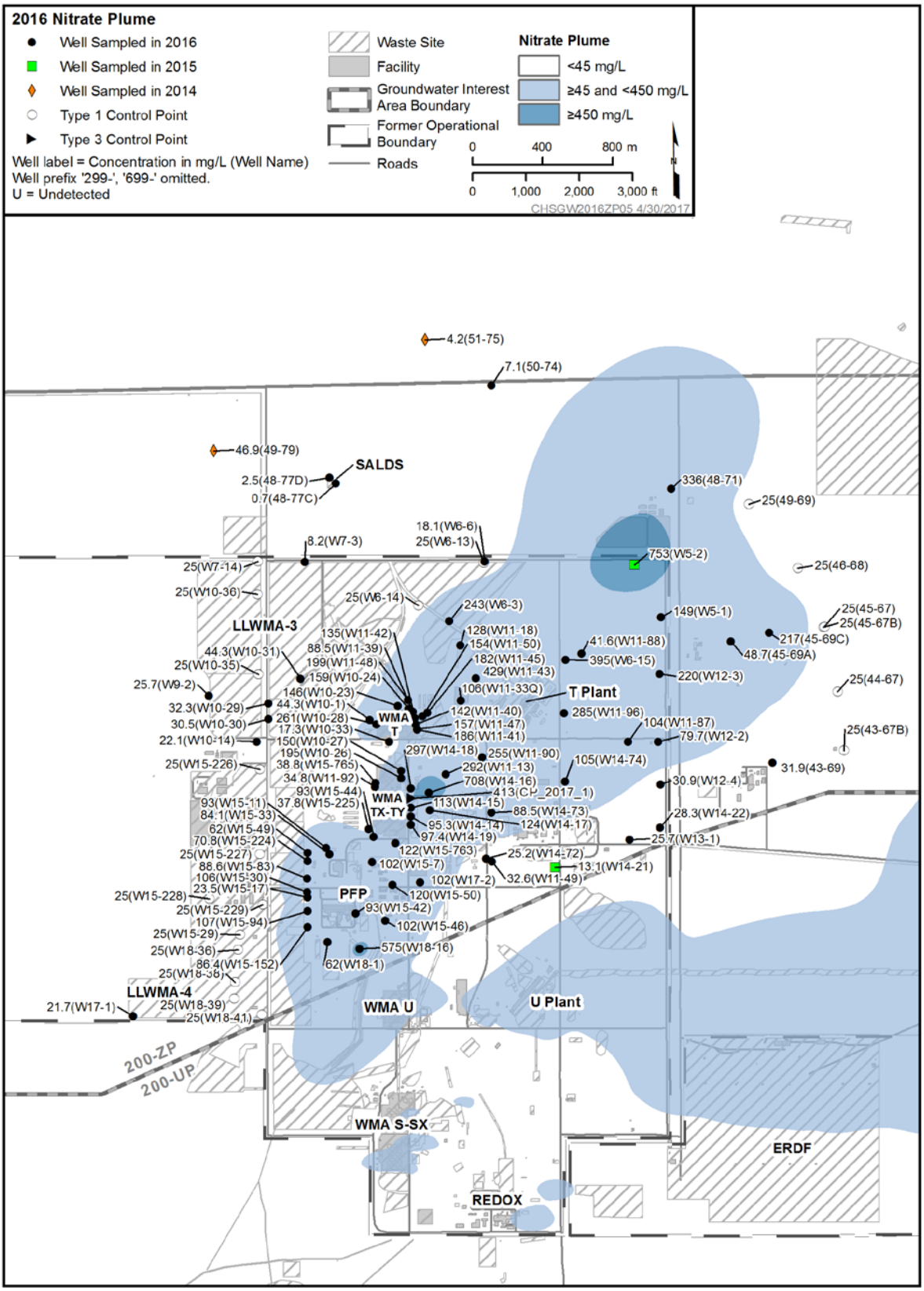


Figure 4-18. Contaminant Plume Map for Nitrate, 2016

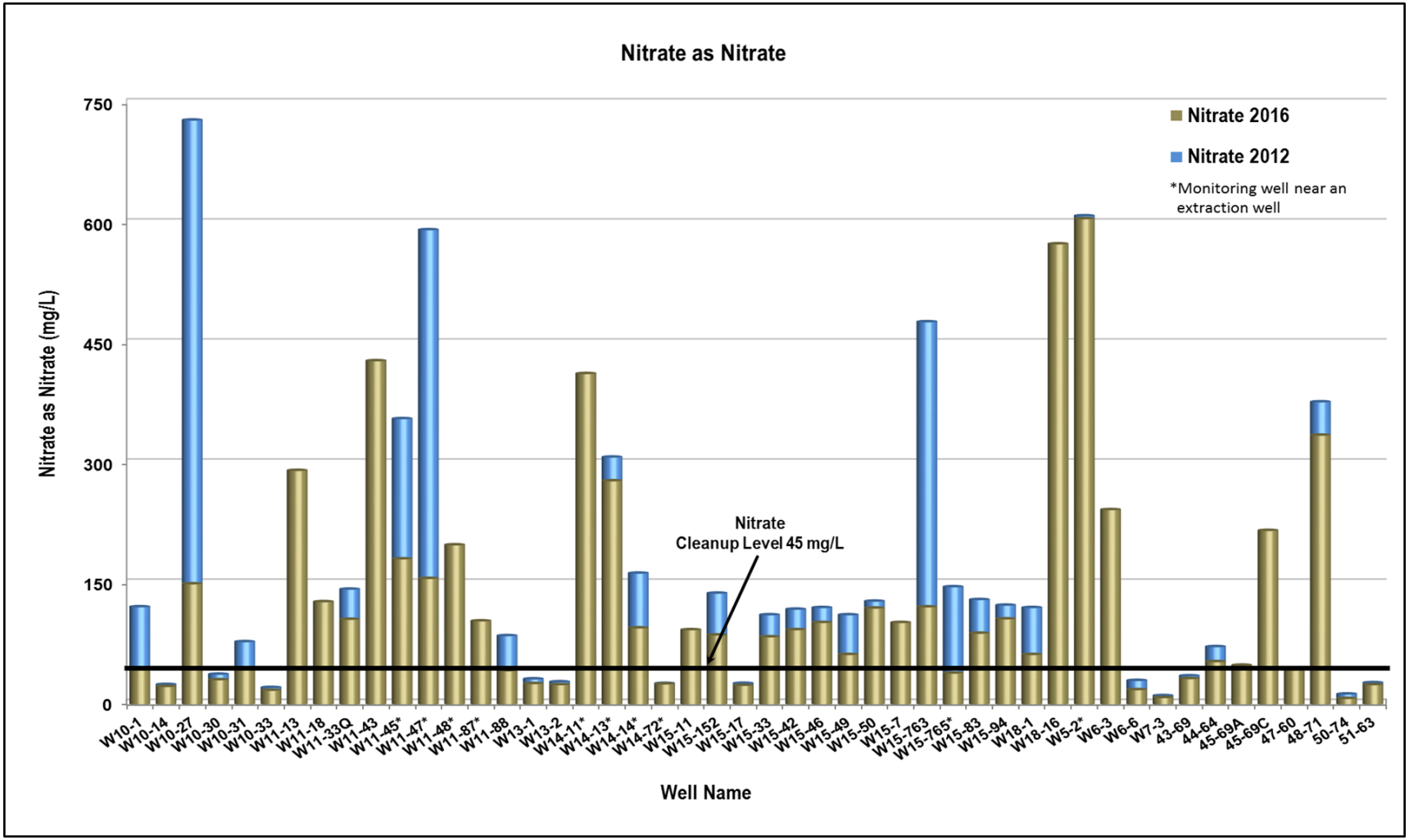


Figure 4-19. Comparison of Nitrate Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Graph

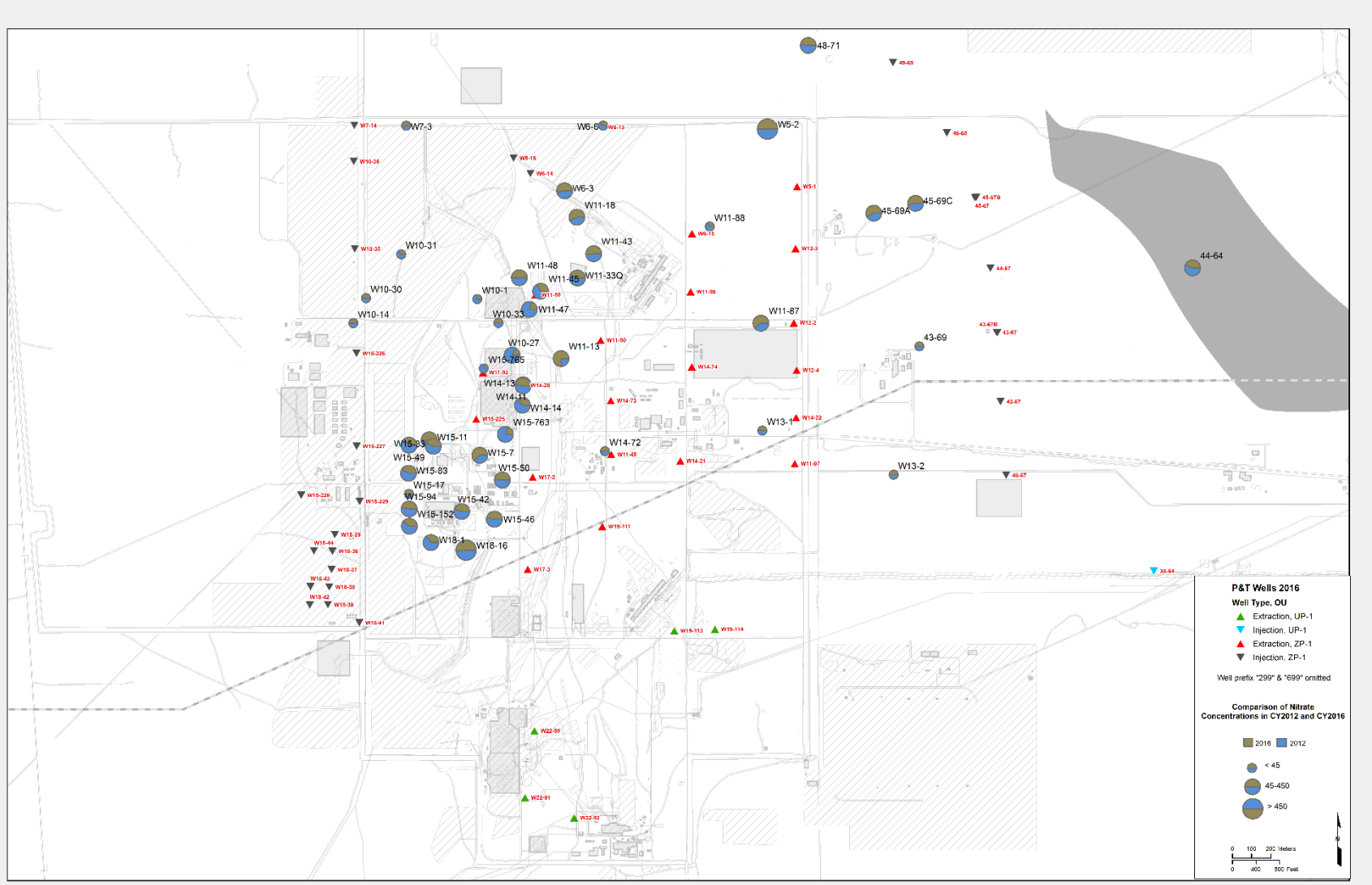


Figure 4-20. Comparison of Nitrate Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Map

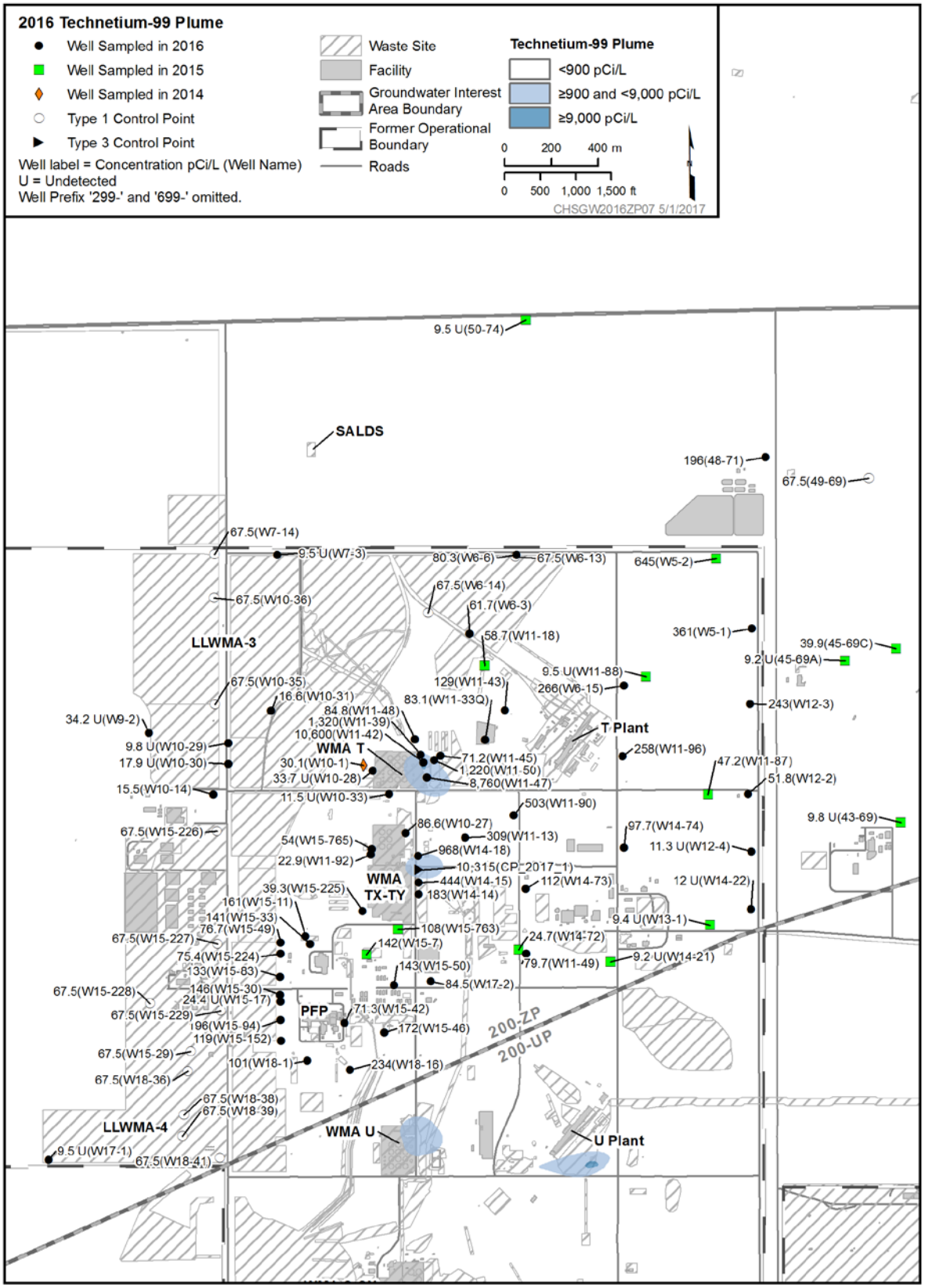


Figure 4-21. Contaminant Plume Map for Technetium-99, 2016

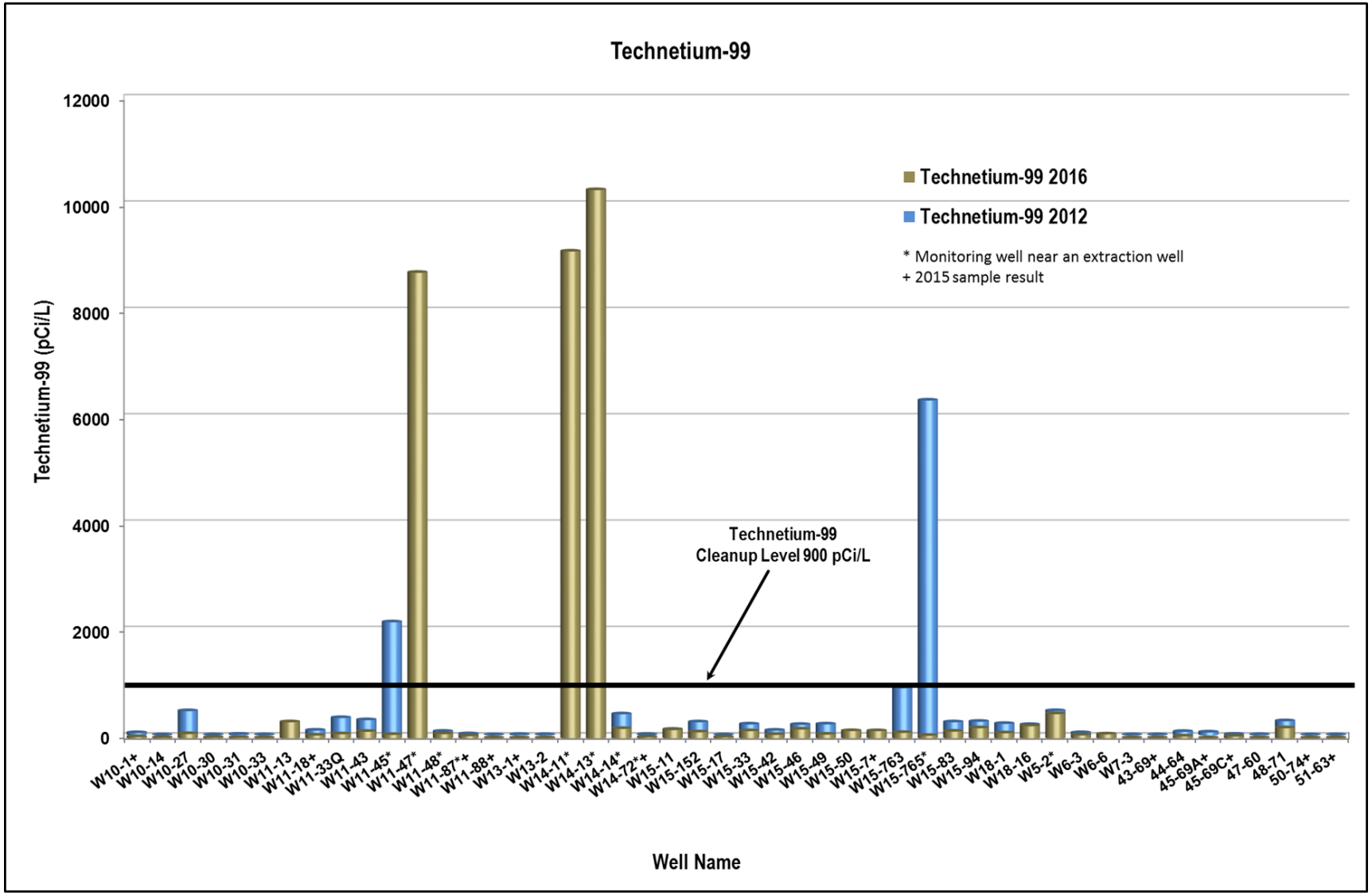


Figure 4-22. Comparison of Technetium-99 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Graph

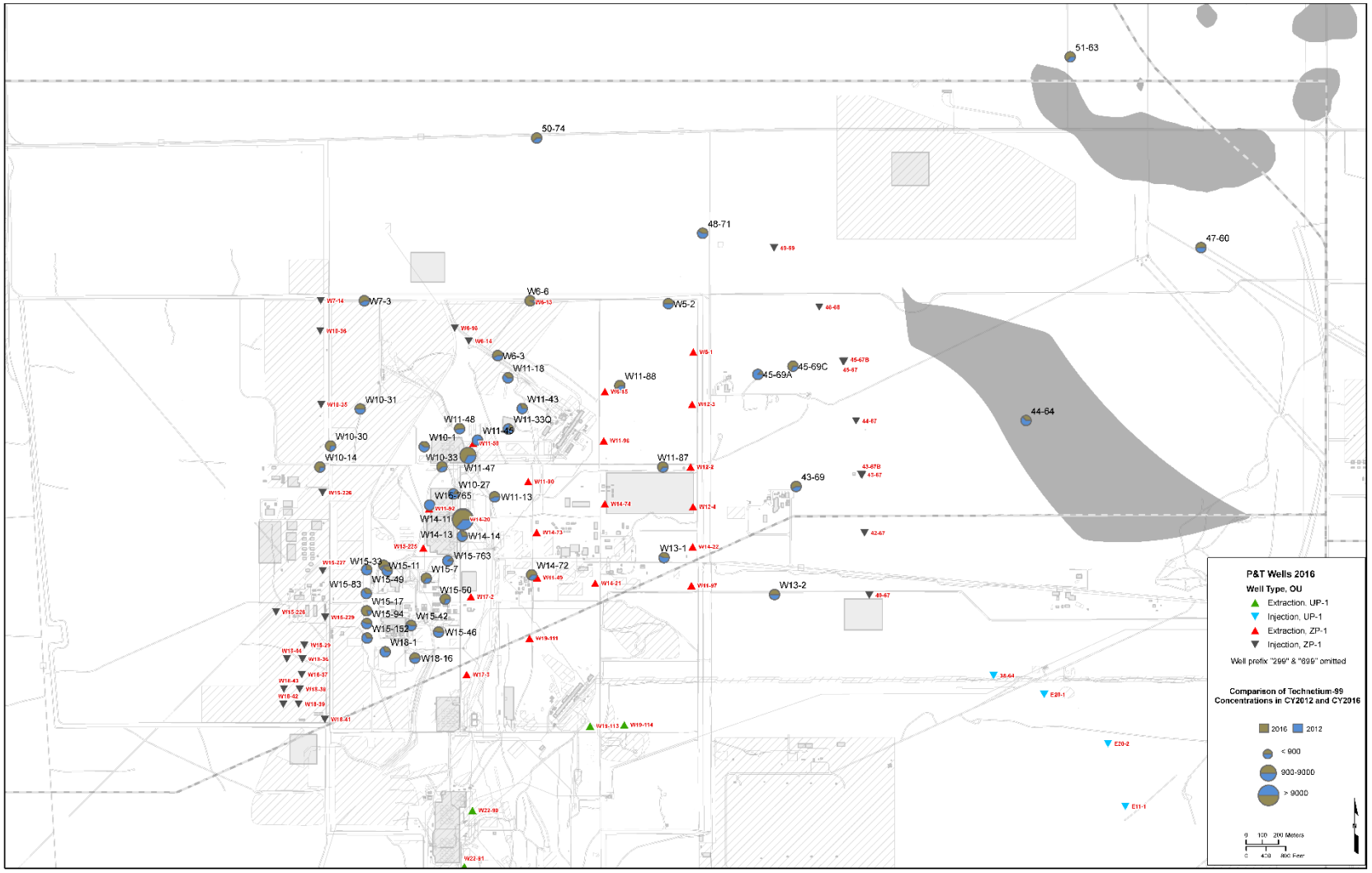


Figure 4-23. Comparison of Technetium 99 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Map

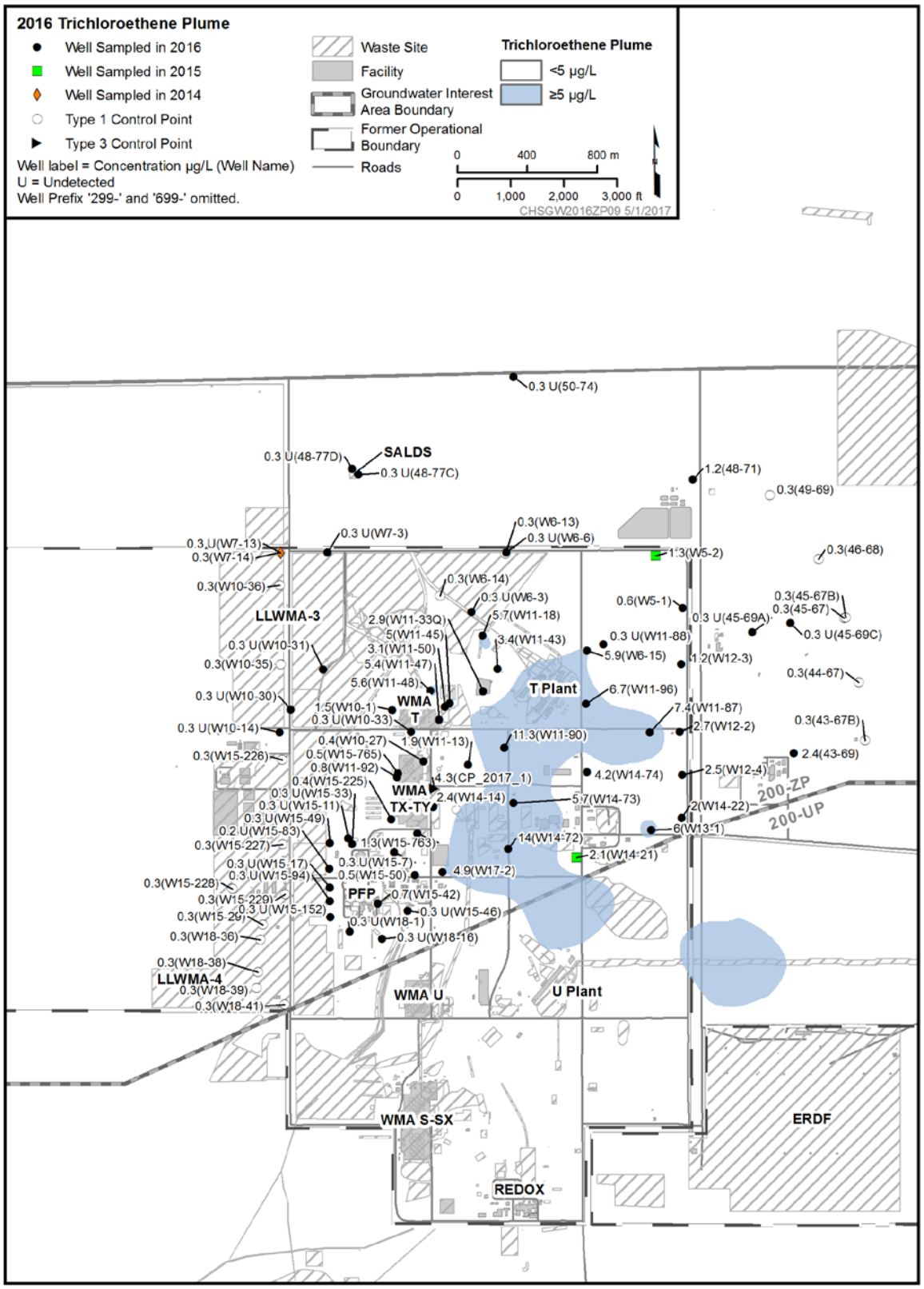


Figure 4-24. Contaminant Plume Map for Trichloroethene, 2016

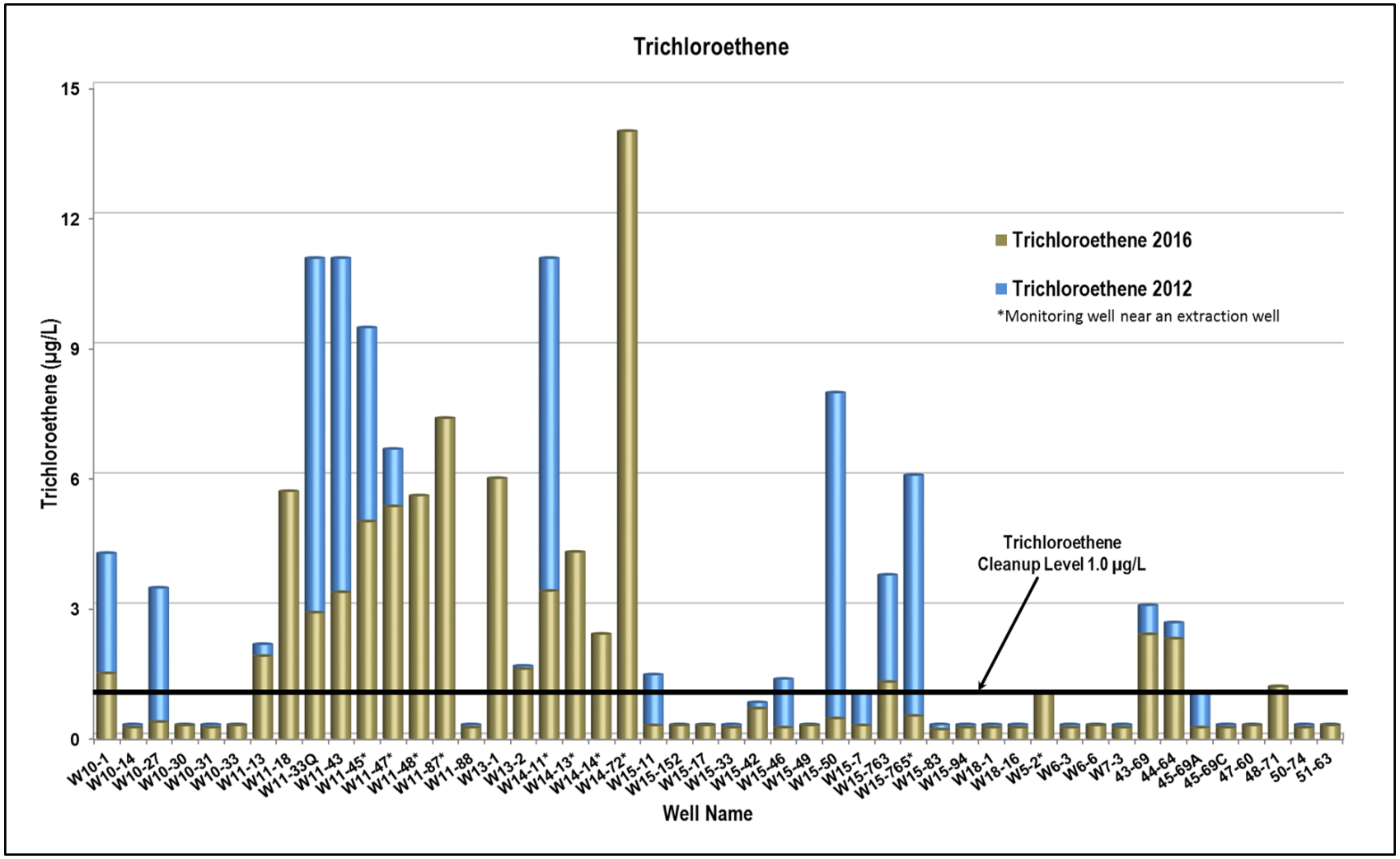


Figure 4-25. Comparison of Trichloroethene Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Graph

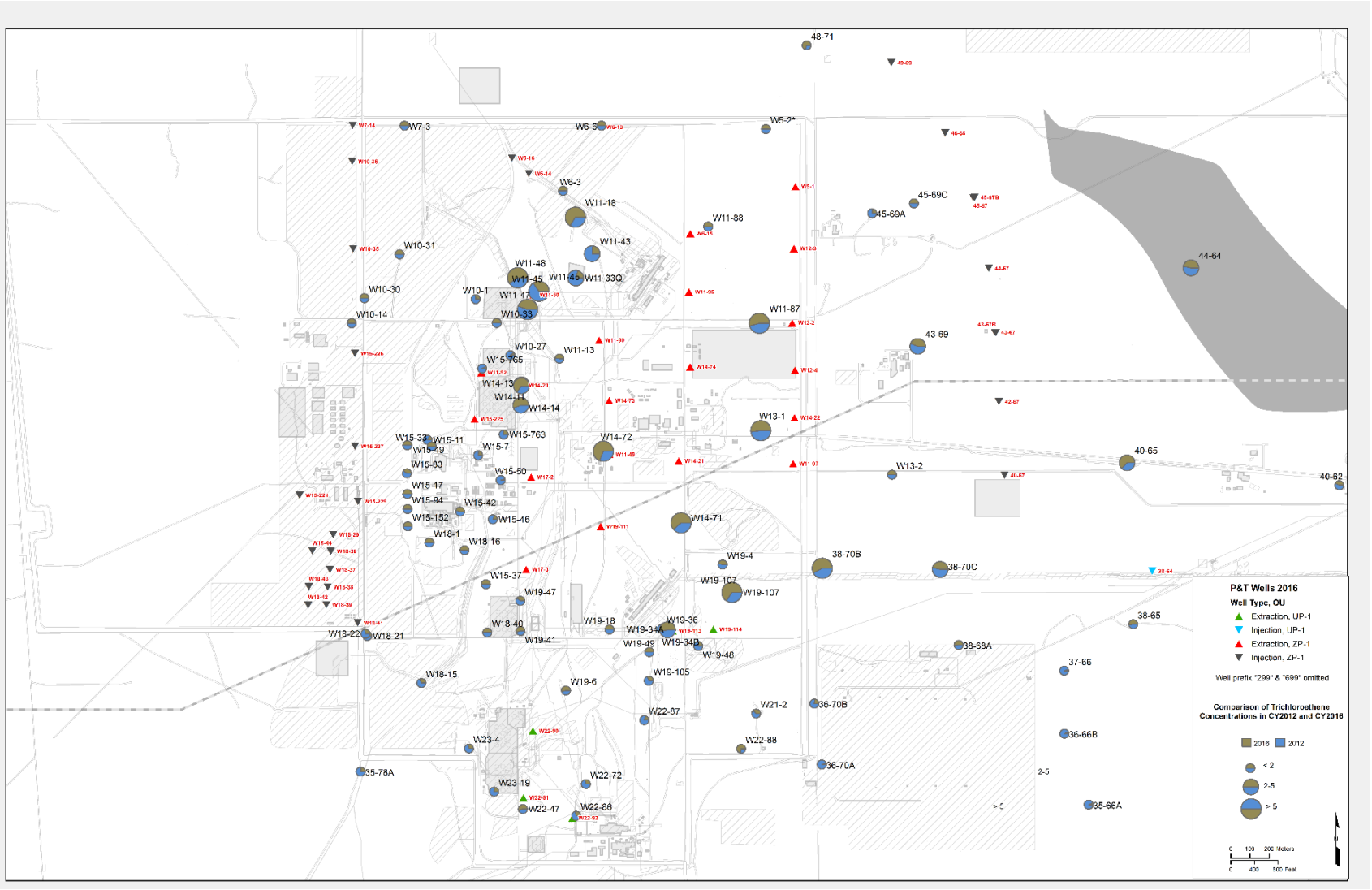


Figure 4-26. Comparison of Trichlorethene Concentrations in 200-ZP-1 and 200-UP-1 OU Monitoring Wells in 2012 and 2016: Map

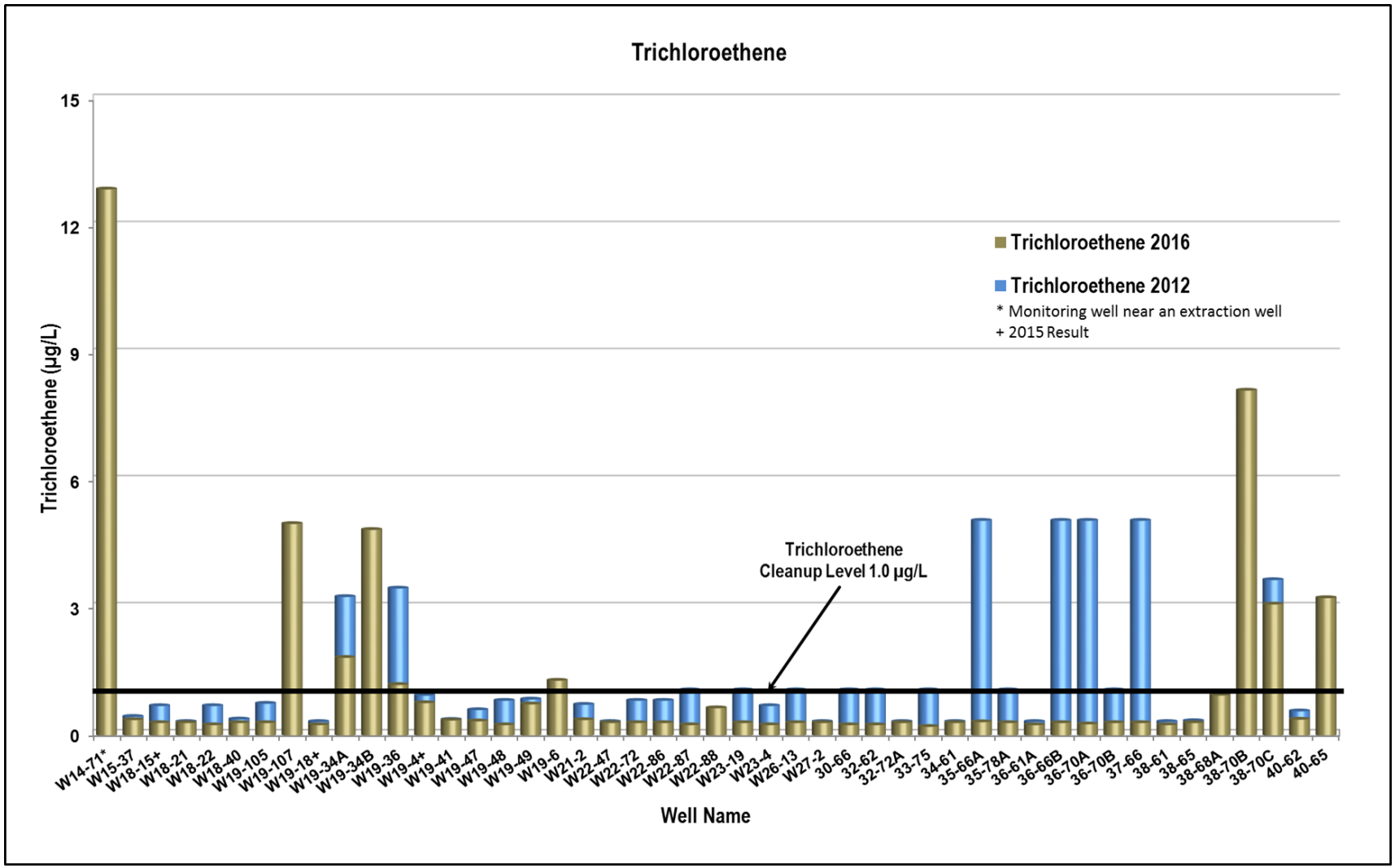


Figure 4-27. Comparison of Trichloroethene Concentrations in 200-UP-1 OU Monitoring Wells in 2012 and 2016; Graph

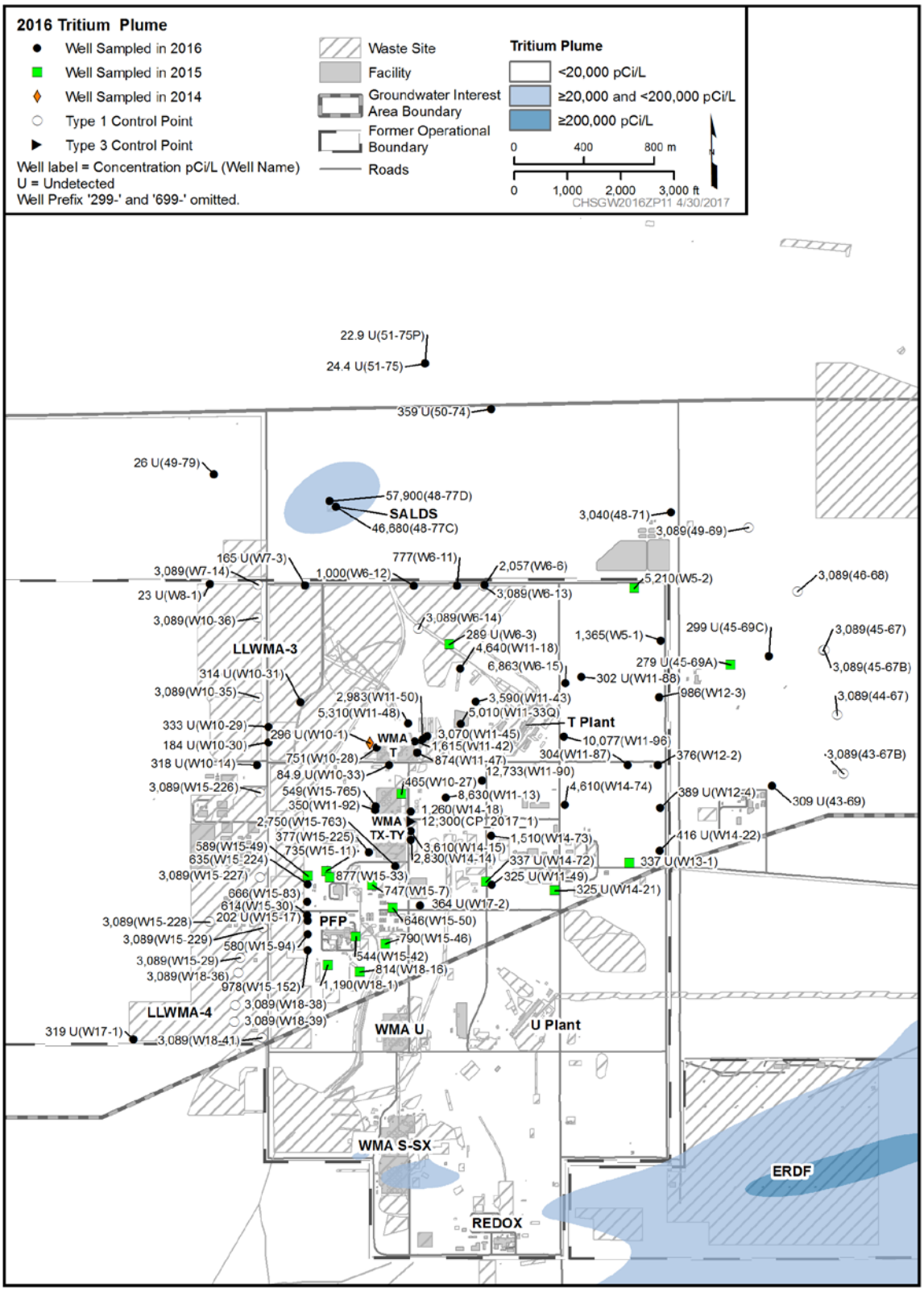


Figure 4-28. Contaminant Plume Map for Tritium, 2016

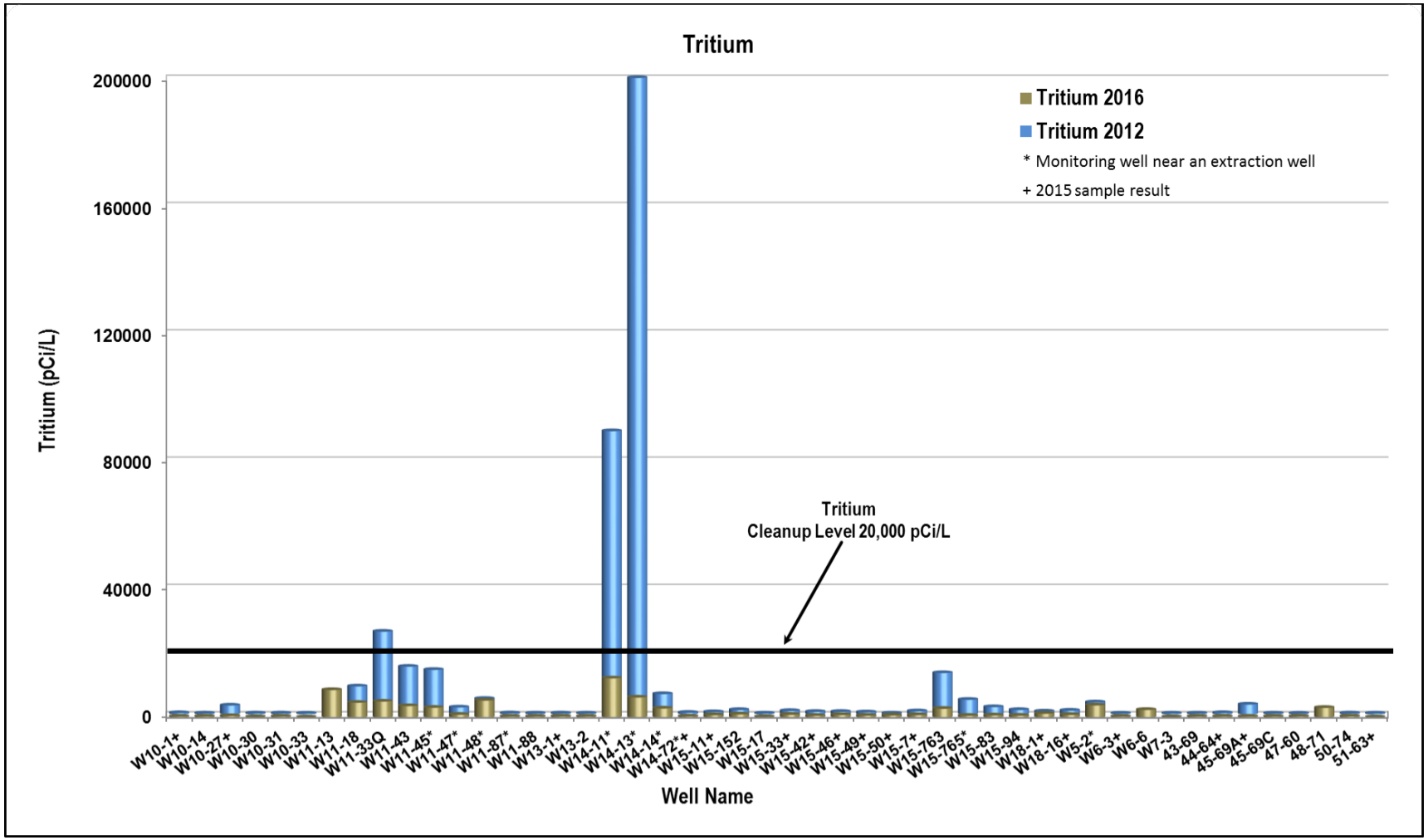


Figure 4-29. Comparison of Tritium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Graph

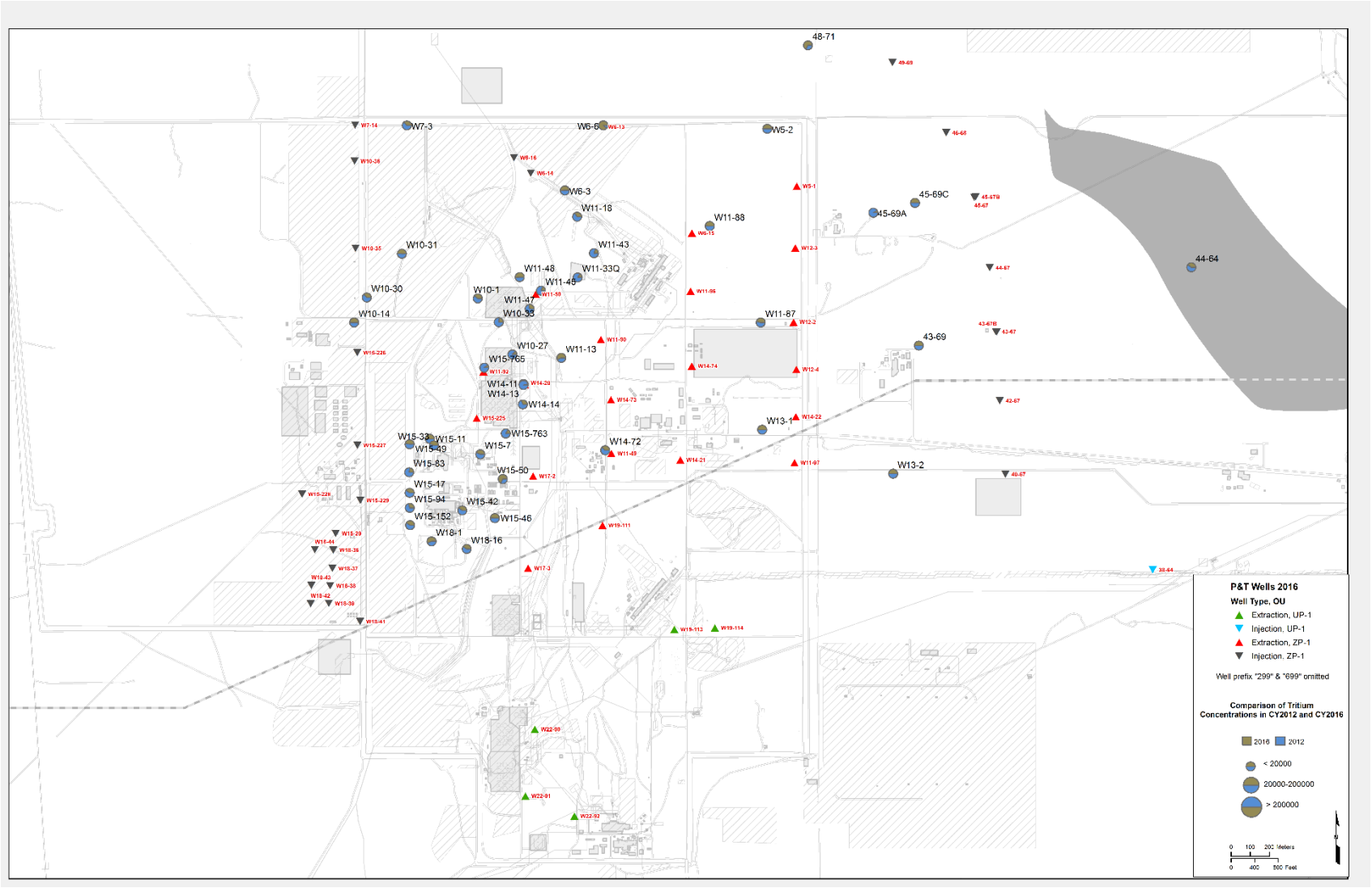


Figure 4-30. Comparison of Tritium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2016: Map

The 200 West P&T baseline data were collected between October 1, 2011 and December 31, 2012 from an extensive network of extraction, injection, and monitoring wells (Figure 4-31).

The monitoring program obtains data from a network of monitoring wells that have been evaluated to develop a constituent-specific set of analyses for each well. For each contaminant (excluding carbon tetrachloride and TCE), each well on the PMP list (DOE/RL-2009-115) was evaluated in the context of geographic location relative to the plume in the 200-ZP-1 OU and the data trends relative to the cleanup level (this evaluation included data collected as part of the PMP efforts, as well as data from as far back as 1990). For VOCs, such as carbon tetrachloride and TCE, the monitoring well network extends into the 200-UP-1 OU (Figure 4-31) in order to track the plume and mass removal to meet the performance metrics provided in the 200-ZP-1 ROD (EPA et al., 2008). The contaminant-specific sampling will be augmented by sampling each well for all COCs to support preparation of the CERCLA 5-year review (data collected in 2016). Sampling of the monitoring well network for all COCs for the CERCLA 5-year review will generate sufficient data for quantitative analysis in support of addressing all nine DSs (presented in DOE/RL-2009-115); however, annual sampling from the contaminant-specific well list will provide data for assessing if there are any new releases of COCs; evaluating concentration trends in high-concentration areas of the plumes; and determining if contamination is expanding downgradient, laterally, or vertically. Therefore, while the 200 West P&T is operating, the list of plume and constituent specific analyses will be evaluated on an annual basis to determine if analyses will be added or dropped from the well, with DOE and EPA concurrence. Extraction well and P&T system data are collected to assess the performance of the system over time and calibrate the parameters of the CPGWM to assist with remedy optimization.

4.3.2 Contaminant Monitoring Data

The CY 2016 contaminant monitoring results for the 200 West Area are summarized by COC in the following subsections. The 2016 average concentrations are presented in Table 4-2. The two-dimensional contaminant plume maps presented in this section were primarily created using data from wells screened in the unconfined aquifer, although data from wells screened below the RLM were considered, where present. Where more than one data point was available for 2016, the average value was typically used. Full details on the preparation of the two-dimensional plume maps presented here are provided in a calculation (ECF-HANFORD-16-0138, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2016 Hanford Site Groundwater Monitoring Report*).

In preparation for this P&T report, 3D depictions of the extent of contamination were also prepared in 2016 for use in groundwater contaminant fate and transport calculations. These calculations are described in Section 4.3.3.

4.3.2.1 Contaminants of Concern

Carbon Tetrachloride. Carbon tetrachloride is the primary COC at the 200-ZP-1 OU. Contamination originated from discharges of wastes related to plutonium processing prior to 1981. The 200-ZP-1 interim P&T system targeted carbon tetrachloride mass removal in the high-concentration area (greater than 2,000 µg/L) of the plume in the upper portion of the aquifer during its operation from 1996 through May 2012 (DOE/RL-2012-36, *200 ZP-1 Interim Pump-and-Treat System Summary Performance Report for Calendar Year 2012*). The final 200-ZP-1 ROD (EPA et al., 2008) reduced the 2,000 µg/L cleanup standard for carbon tetrachloride targeted by the 1995 interim ROD (EPA/ROD/R10-95/114, *EPA Superfund Record of Decision: Hanford 200-Area (USDOE) OU 200-ZP-1, Benton County, WA 5/24/95*) to 3.4 µg/L and targeted the entire thickness of the plume. Figure 4-8 illustrates the carbon tetrachloride distribution at concentrations greater than 3.4 µg/L based on maximum sample concentrations during 2016 (see Section 4.3.4).

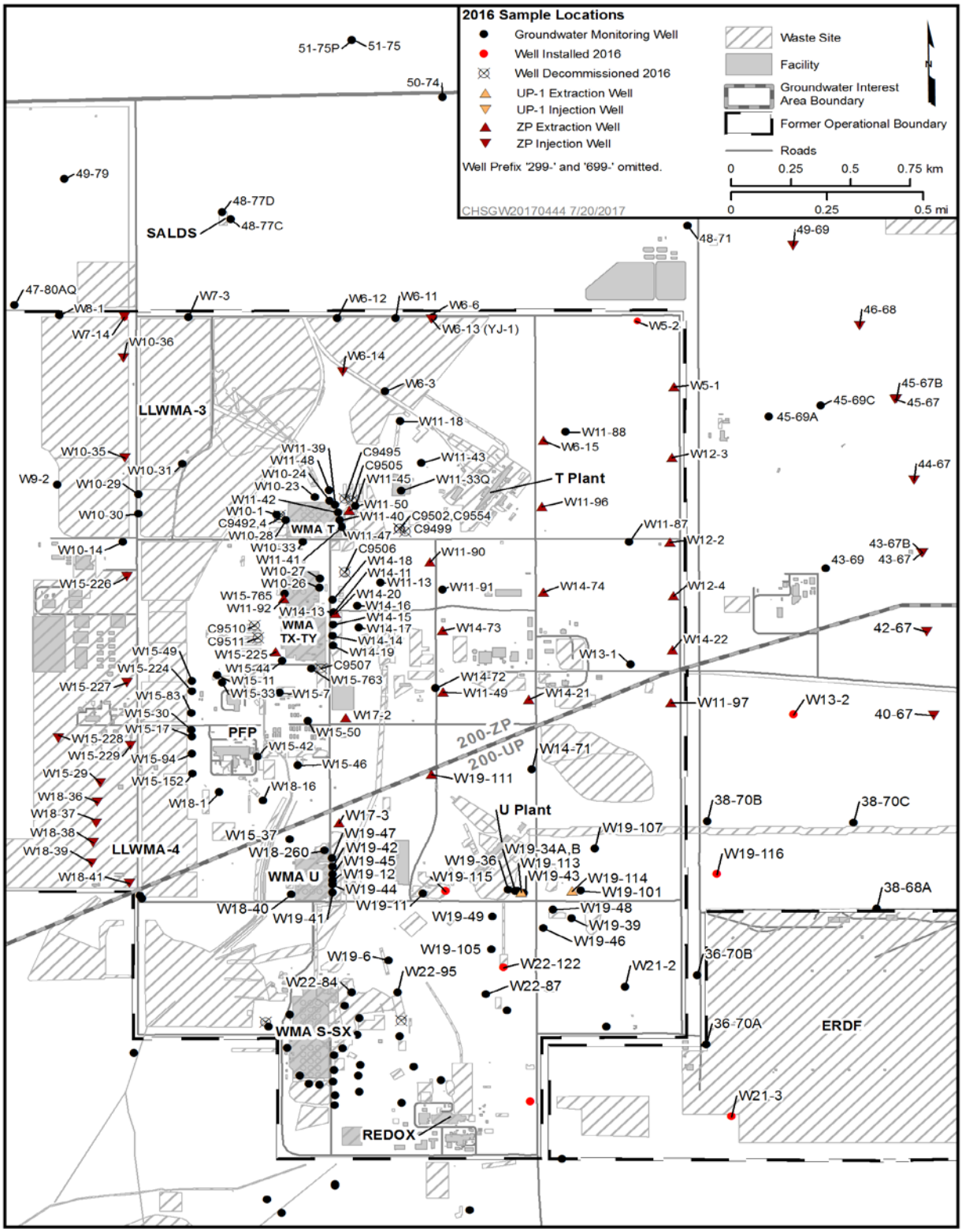


Figure 4-31. 200-ZP-1 OU Groundwater Well Network, 2016

Table 4-2. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2016

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Techneitum-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2016?
299-W10-1	430.0	16.3	2.7	<0.24+	44.3	30+	1.50	296+	1.10	Yes
299-W10-14	<0.1	15.0+	2.4+	<0.58	22.1	16	<0.25	<318	0.90	Yes
299-W10-27	53.0	24.6	15.7	<0.47	150.3	87	0.38	465+	1.50	Yes
299-W10-30	18.3	2.6+	3.4+	<0.59	30.5	<18	<0.30	<184	0.89	Yes
299-W10-31	17.0	2.5+	3.1+	<0.39	44.3	17	<0.25	<314	3.92	Yes
299-W10-33	<0.3	2.0	<1.5	<0.85+	17.3	<12	<0.30	<85	1.32	Yes
299-W11-13	190.0	77.4	16.0	<0.63	292.0	309	1.90	8,630	1.10	Yes
299-W11-18	508.0	39.3	36.0	<0.88	128.0	59+	5.70	4,640	1.60	Yes
299-W11-33Q	290.0	18.0	27.0	<0.70	106.0	83	2.90	5,010	0.72	Yes
299-W11-43	263.0	166.0	180.0	<0.99	429.0	129	3.40	3,590	2.99	Yes
299-W11-45	730.0	47.0	45.5	<0.79	181.5	71	5.00	3,070	0.89	Yes
299-W11-47	1,160.0	31.5	30.0	1.10	157.0	8,760	5.40	874	0.92	Yes
299-W11-48	880.0	57.0	59.0	<0.33	199.0	85	5.60	5,310	1.20	Yes
299-W11-87	2,315.0	13.1	10.5	<0.56+	104.0	47+	7.40	304	1.54	Yes
299-W11-88	1.0	<1.5	<1.5	<0.50	41.6	<10+	<0.30	<302	1.03	Yes
299-W13-1	1,500.0	72.7+	11.7+	<0.19	25.7	<9+	6.0	<337+	0.90+	Yes
299-W13-2	62.7	4.2	<1.5	<0.67	24.3	<9	1.60	313	2.00	Yes
299-W14-11	845.0	63.9	65.0	1.01	413.0	9,160	3.40	12,300	2.57	Yes
299-W14-13	1,000.0	15.3	10.7	0.85	279.0	10,315	4.30	6,290	2.45	Yes
299-W14-14	417.0	8.3	7.3	<0.40	95.3	183	2.40	2,830	1.02	Yes

Table 4-2. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2016

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Techneitum-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2016?
299-W14-71	801.0	—	—	—	—	—	12.90	—	—	Yes
299-W14-72	1,200.0	7.3+	2.1+	<0.29+	25.2	25+	14.00	<337+	0.73+	Yes
299-W15-11	117.0	8.4+	8.1+	<0.51+	93.0	161	<0.30	735+	0.86+	Yes
299-W15-152	4.1	10.2	8.5+	<0.51	86.4	119	<0.25	978	2.35	Yes
299-W15-17	1.6	15.4	1.6+	<0.70	23.5	<24	<0.30	<202	0.85	Yes
299-W15-33	69.0	9.4+	7.2+	<0.29+	84.1	141	<0.25	877+	0.91+	Yes
299-W15-37	157.0	—	—	—	—	—	0.37	—	—	Yes
299-W15-42	77.0	11.2+	10.0+	<0.74	93.0	71	0.70	544+	1.61+	Yes
299-W15-46	39.0	6.5+	6.5+	<0.19+	102.0	172	<0.25	790+	0.69+	Yes
299-W15-49	65.0	8.0+	9.7+	<0.69+	62.0	77	0.30	589+	0.83+	Yes
299-W15-50	160.0	7.4+	7.9+	<0.15+	120.0	143	0.46	646+	0.80+	Yes
299-W15-7	163.0	6.8+	<1.5+	<0.85+	102.0	142+	0.30	747+	1.06+	Yes
299-W15-763	310.0	107.7	8.6	<0.27+	121.5	108	1.30	2,750	0.99	Yes
299-W15-765	64.0	5.6	4.2	0.88+	38.8	54	0.52	549	1.12	Yes
299-W15-83	35.5	6.4	5.8+	<0.48	88.6	133	<0.25	666	0.97	Yes
299-W15-94	15.7	8.4	8.3+	<0.81	106.5	196	<0.30	580	0.95	Yes
299-W18-1	4.3	8.0+	6.6+	<0.68	62.0	101	<0.25	1,190+	2.74+	Yes
299-W18-15+	18.3	—	—	—	—	—	<0.30	—	—	No+
299-W18-16	33.0	11.2+	12.3+	<0.25+	575.0	234	<0.25	814+	2.85+	Yes
299-W18-21	0.33	—	—	—	—	—	<0.30	—	—	Yes

Table 4-2. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2016

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Techneitum-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2016?
299-W18-22	1.2	—	—	—	—	—	<0.25	—	—	Yes
299-W18-40	98.3	—	—	—	—	—	<0.30	—	—	Yes
299-W19-105	40.0	—	—	—	—	—	<0.30	—	—	Yes
299-W19-107	150.0	—	—	—	—	—	5.00	—	—	Yes
299-W19-18+	<0.1	—	—	—	—	—	<0.25	—	—	No+
299-W19-34A	91.3	—	—	—	—	—	1.84	—	—	Yes
299-W19-34B	106.0	—	—	—	—	—	4.86	—	—	Yes
299-W19-36	12.0	—	—	—	—	—	1.20	—	—	Yes
299-W19-4+	48.0	—	—	—	—	—	0.77	—	—	No+
299-W19-41	150.0	—	—	—	—	—	<0.36	—	—	Yes
299-W19-47	126.0	—	—	—	—	—	0.34	—	—	Yes
299-W19-48	22.0	—	—	—	—	—	<0.25	—	—	Yes
299-W19-49	305.0	—	—	—	—	—	0.74	—	—	Yes
299-W19-6	53.0	—	—	—	—	—	1.30	—	—	Yes
299-W21-2	29.4	—	—	—	—	—	0.37	—	—	Yes
299-W22-47	128.0	—	—	—	—	—	<0.30	—	—	Yes
299-W22-72	69.4	—	—	—	—	—	<0.30	—	—	Yes
299-W22-86	16.3	—	—	—	—	—	<0.30	—	—	Yes
299-W22-87	15.0	—	—	—	—	—	<0.25	—	—	Yes
299-W22-88	11.3	—	—	—	—	—	0.65	—	—	Yes

Table 4-2. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2016

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Techneitum-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2016?
299-W23-19	84.4	—	—	—	—	—	<0.30	—	—	Yes
299-W23-4	63.0	—	—	—	—	—	<0.25	—	—	Yes
299-W26-13	0.6	—	—	—	—	—	<0.30	—	—	Yes
299-W27-2	5.1	—	—	—	—	—	<0.30	—	—	Yes
299-W5-2+	232.0	76.8	21.7	0.87	606.4	461.1	1.0	3,802	1.34	Yes
299-W6-3	<0.1	20.2+	9.2+	<0.16+	243.0	62	<0.25	<289+	0.95+	Yes
299-W6-6	<0.3	26.7	2.6	<0.58	18.1	80	<0.30	2,390	1.10+	Yes
299-W7-3	<0.1	20.6	4.6	<0.84	8.2	<10	<0.30	<165	1.00	Yes
699-30-66	0.5	—	—	—	—	—	<0.25	—	—	Yes
699-32-62	0.1	—	—	—	—	—	<0.25	—	—	Yes
699-32-72A	0.8	—	—	—	—	—	<0.30	—	—	Yes
699-33-75	6.6	—	—	—	—	—	<0.21	—	—	Yes
699-34-61	0.8	—	—	—	—	—	<0.30	—	—	Yes
699-35-66A	1.0	—	—	—	—	—	0.32	—	—	Yes
699-35-78A	33.2	—	—	—	—	—	<0.30	—	—	Yes
699-36-61A	0.2	—	—	—	—	—	<0.25	—	—	Yes
699-36-66B	3.4	—	—	—	—	—	0.30	—	—	Yes
699-36-70A	3.6	—	—	—	—	—	<0.27	—	—	Yes
699-36-70B	12.2	—	—	—	—	—	0.30	—	—	Yes
699-37-66	2.0	—	—	—	—	—	0.30	—	—	Yes

Table 4-2. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2016

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Techneitum-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2016?
699-38-61	<0.1	—	—	—	—	—	<0.25	—	—	Yes
699-38-65	1.0	—	—	—	—	—	0.30	—	—	Yes
699-38-68A	7.6	—	—	—	—	—	0.95	—	—	Yes
699-38-70B	173.0	—	—	—	—	—	8.15	—	—	Yes
699-38-70C	15.0	—	—	—	—	—	3.10	—	—	Yes
699-40-62	0.6	—	—	—	—	—	0.38	—	—	Yes
699-40-65	7.3	—	—	—	—	—	3.25	—	—	Yes
699-43-69	210.0	81.0	24.0	<0.35	31.9	<10+	2.40	<309	1.40	Yes
699-44-64	13.0	12.8+	7.3+	<0.23+	53.1	41	2.30	<302+	1.71+	Yes
699-45-69A	0.6	33.9+	8.2+	<0.54+	48.7	<9+	<0.25	<279+	1.54+	Yes
699-45-69C	28.0	31.0	27.0	<0.49	217.0	40+	<0.25	<299	1.27+	Yes
699-47-60	<0.3	48.7	5.5	<0.40	42.5	<11	<0.30	<322	2.46	Yes
699-48-71	190.0	325.0	85.0	<0.60	336.0	196	1.20	3,040	1.60	Yes
699-50-74	<0.2	7.3+	4.5+	<0.32+	7.1	<10+	<0.25	<359	1.40+	Yes
699-51-63	<0.3	2.5+	1.6+	<0.35+	24.3	<11+	<0.30	<105+	2.22+	Yes

Notes: Requirements are from DOE/RL-2009-124, *200 West Area Pump and Treat Operations and Maintenance Plan*, and DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*.

Units are µg/L for chemical contaminants and pCi/L for radionuclides.

Concentrations are averaged for all sample results collected throughout the year from each monitoring well for each contaminant.

— = well not scheduled for analysis

\+ = 2015 sample result

++ = well not sampled because it is dry

The area of the carbon tetrachloride plume is greater than 17.98 km^2 (6.94 mi^2), extending from the western border of the 200 West Area to about 1 km (0.6 mi) east of Route 3, and from the southern edge of the 200-UP-1 OU northward nearly to Route 11A.

The CY 2016 carbon tetrachloride sample results are compared to the baseline concentrations. Trends in carbon tetrachloride concentrations are mixed. During 2016, the majority of the high-concentration core of the carbon tetrachloride plume resided within the extent of hydraulic containment of the 200 West P&T extraction wells (Figure 4-7). Because the carbon tetrachloride plume in the 200-UP-1 OU is attributed to contamination migrating from the 200-ZP-1 OU, concentrations of carbon tetrachloride are monitored in 47 wells in the 200-UP-1 OU (DOE/RL-2009-115).

During 2016, two wells exceeded 2,000 µg/L of carbon tetrachloride. Extraction well 299-W6-15 had a maximum concentration of 2,500 µg/L, and monitoring well 299-W11-87 was 2,315 µg/L. Wells 299-W13-1, 299-W11-90, and 299-W14-72 had the next highest concentrations at 1,500 µg/L, 1,400 µg/L, and 1,200 µg/L, respectively. Extraction well 299-W14-20 (located east of WMA TX-TY) and groundwater monitoring well 299-W11-47 (located east of WMA T) had the next highest concentrations at 1,200 µg/L and 1,160 µg/L, respectively. Monitoring wells with increasing concentrations are located near extraction wells that are drawing contamination from the surrounding area. Of the 95 monitoring wells sampled in 2016 in the 200 West Area, 91 wells were below 1,000 µg/L, and 25 of the 91 wells were below the cleanup level (3.4 µg/L).

Figure 4-9 illustrates a comparison of the 2012 and 2016 carbon tetrachloride concentrations in the 200-ZP-1 OU monitoring wells; Figure 4-11 illustrates the comparison for the 200-UP-1 OU monitoring wells. During 2016 there were nine monitoring wells with increasing concentrations of carbon tetrachloride in the 200-ZP-1 OU and eleven monitoring wells with increasing concentrations of carbon tetrachloride in the 200-UP-1 OU. Those monitoring wells are shown in Figure 4-10 in relationship to the extraction wells for both 200-ZP-1 and 200-UP-1 wells. Table 4-3 highlights a comparison of monitoring wells with increasing or decreasing concentrations, and those wells with concentrations remaining stable for carbon tetrachloride in 2016.

After only 4.5 years of operation, the effectiveness of the 200 West P&T was evident by the declining carbon tetrachloride concentrations in nearly one-half of the monitoring wells. Carbon tetrachloride concentrations declined in 46 of 95 monitoring wells sampled, 20 wells had increasing concentrations, and 29 wells had concentrations about the same as 2012 (less than 20% difference between 2012 and 2016 concentrations). Lower concentrations in the extraction wells are caused by concentration averaging because in addition to water from within the plumes being drawn into the extraction wells, water from outside the plumes (laterally and vertically) is also being drawn in, diluting the plume concentrations.

Chromium (Total and Hexavalent). Chromium contamination is found at levels above the cleanup standard (100 µg/L for total chromium and 48 µg/L for hexavalent chromium) beneath the SSTs at WMA T and at WMA TX-TY. Chromium is analyzed in groundwater samples using two different methods: inductively coupled plasma, which yields a result for total chromium (i.e., trivalent and hexavalent chromium combined); and a colorimetric method (ultraviolet/visible light absorption), which yields a result for only the hexavalent form. The HEIS database includes results for both total chromium and hexavalent chromium. Dissolved chromium monitoring results, as referred to in this chapter, includes sample results for mobile chromium consisting of hexavalent chromium and filtered total chromium. Figure 4-12 shows the extent of the dissolved chromium plume in the unconfined aquifer.

In 2016, the 200-ZP-1 OU maximum chromium concentration (420 µg/L unfiltered, total chromium) was downgradient from WMA TX-TY in 299-W10-27, an increase from 115 µg/L in this well in 2012. The increase is likely attributed to particulates: the Cr(VI) concentration representing dissolved chromium was only 30 µg/L. Due to the potential impact of well corrosion in the samples, both filtered and unfiltered samples will be taken in the future and will likely include iron and nickle to "other constituents" in the SAP during the next revision. Concentrations exceeding the cleanup standard were found at 5 of the 48 monitoring wells in the 200-ZP-1 OU. The dissolved chromium plumes are migrating eastward in the OU and are within the capture zones of the 200 West P&T extraction wells (Figure 4-12). A comparison of sampling results in 2012 and 2016 for dissolved chromium indicates that concentrations are declining (Figure 4-13). Figure 4-14 represents a comparison of dissolved chromium concentrations in relationship to the extraction wells. Table 4-3 highlights a comparison of the monitoring wells in 2016 with increasing or decreasing concentrations, and those wells with concentrations remaining stable.

Dissolved chromium concentration declined 32% in one of the five monitoring wells with concentrations exceeding the cleanup level (299-W11-48); one well had an increase in concentration (699-48-71), and three wells had concentrations similar to those observed in 2012. Well 299-W11-48 is located next to extraction well 299-11-50 drawing in contaminated groundwater. Well 699-48-71 has increasing chromium because it is in the path of the plume migration.

Iodine-129. Iodine-129 concentrations exceed the 1 pCi/L cleanup standard in three wells in 200-ZP-1. Iodine-129 sources include past leaks from SSTs containing metal and liquid waste from chemical processing and plant operations, and liquid waste disposal facilities (e.g., cribs and trenches) adjacent to the tank farms. Figure 4-15 shows the extent of the iodine-129 plume in the unconfined aquifer. In 2016, the maximum concentration of 1.20 pCi/L was at 299-W14-11 (Table 4-4), a monitoring well downgradient of WMA TX-TY. Concentrations also exceeded the 1 pCi/L cleanup level in 299-W11-47 (with 1.10 pCi/L) located east of WMA T and in extraction well 299-W11-96 (with 1.08 pCi/L) east of T Plant. Well 299-W5-2 exceeded 1 pCi/L in 2015 and was not sampled in 2016. The iodine-129 plume is migrating eastward as other contaminant plumes in the OU and is within the capture zone of the 200 West P&T extraction wells (Figure 4-16). Figure 4-17 represents a comparison of iodine-129 concentrations in relationship to the extraction wells. Table 4-3 highlights a comparison of the monitoring wells with increasing or decreasing concentrations, and those wells with concentrations remaining stable for iodine-129 in 2016.

During operations in 2016, iodine-129 was detected in the influent to the radiological treatment system at low levels (around 1 pCi/L) and was removed by the Purolite resin to less than cleanup level concentrations. The iodine-129 detection limit is approximately 0.6 pCi/L. Concentrations declined in the monitoring wells sampled in 2012 and 2016 (Figures 4-16 and 4-17). Iodine-129 concentrations in 2016 are below the cleanup level of 1 pCi/L in 46 of 48 monitoring wells as expected because it is a small plume and concentrations are anticipated to rapidly diminish.

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Table 4-3. Comparison of COCs Concentration in Monitoring Wells in 2012 and 2016

Well	Carbon Tetrachloride		Hexavalent Chromium		Chromium		Iodine-129		Nitrate		Technetium-99		Trichloroethene		Tritium	
	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016
W10-1	950	430	2	2.7	30.2	16.3	0.2	0.24	118	44.3	47.4	30.1	4.2	1.5	443	296
W10-14	1	0.13	2	2.4	10.3	15	0.2	0.58	21	22.1	6	15.5	0.25	0.25	320	318
W10-27	580	53	105	15.7	115	24.6	0.38	0.474	726	150.3	460	86.6	3.4	0.38	2800	465
W10-30	6.4	18.3	2	3.4	2.76	2.6	0.32	0.59	33.8	30.5	7	17.9	0.25	0.3	330	184
W10-31	29	17	2	3.1	3.17	2.5	0.2	0.39	74.4	44.3	18	16.6	0.25	0.25	330	314
W10-33	0.3	0.3	2	1.5	1.23	2	0.2	0.85	17.2	17.3	7	11.5	0.25	0.3	280	84.9
W11-13	270	190	2	16	50.8	77.4	0.2	0.627	95.2	292	240	309	2.1	1.9	6700	8630
W11-18	330	508	24.6	36	29.9	39.3	0.77	0.878	97.4	128	94	58.7	2.9	5.7	8800	4640
W11-33Q	730	290	2	27	74.6	18	2.65	0.699	140	106	330	83.1	11	2.9	26000	5010
W11-43	780	263	187	180	167	166	0.25	0.986	385	429	290	129	11	3.37	15000	3590
W11-45	1200	730	149	45.5	130	47	0.88	0.79	353	181.5	2130	71.2	9.4	5	14000	3070
W11-47	1200	1160	129	30	132	31.5	0.64	1.1	589	157	4300	8760	6.6	5.35	2200	874
W11-48	400	880	87.3	59	62.3	57	0.2	0.333	193	199	73	84.8	3.8	5.6	4900	5310
W11-87	2200	2315	8	10.5	5.63	13.1	0.2	0.38	66.2	104	26	47.2	6.2	7.385	360	303.5
W11-88	0.3	0.98	2	1.5	3.92	1.5	0.2	0.499	81.9	41.6	6	9.54	0.25	0.25	310	302
W13-1	1800	1500	2	11.7	4.96	72.7	0.2	0.19	27.9	25.7	12	9.39	5.6	6	330	337
W13-2	63	63	1.5	1.5	4.2	4.2	0.67	0.666	24.3	24.3	9.4	9.44	1.6	1.6	313	313
W14-11	1700	845	65.9	65	47.7	63.9	0.88	1.01	291	413	3500	9160	11	3.4	89000	12300
W14-13	390	1000	339	10.7	296	15.3	16	0.85	305	279	5900	10315	2.3	4.3	200000	6290
W14-14	470	417	20	7.3	29.2	8.3	0.98	0.4	160	95.25	400	183	1.9	2.41	6400	2830
W14-72	950	1200	2	2.1	8.15	7.3	0.2	0.29	22.3	25.2	14	24.7	6.3	14	540	337
W15-11	1100	117	2	8.1	6.04	8.4	0.2	0.51	88.5	93	110	161	1.4	0.3	730	735
W15-152	15	4.1	11	8.5	10.8	10.2	0.2	0.505	135	86.4	250	119	0.25	0.3	1400	978
W15-17	0.97	1.63	8	1.6	15.8	15.4	0.35	0.696	22.4	23.5	6	24.4	0.25	0.3	300	202
W15-33	80	69	8.3	7.2	8.24	9.4	0.2	0.29	108	84.1	210	141	0.25	0.25	1100	877
W15-42	270	77	5.2	10	7.66	11.2	0.2	0.736	115	93	93	71.3	0.76	0.69	810	544
W15-46	510	39	3.7	6.5	5.71	6.5	0.2	0.186	117	102	202	172	1.3	0.25	825	790
W15-49	55	65	6.8	9.7	7.99	8	0.2	0.687	108	62	210	76.7	0.25	0.3	670	589
W15-50	1900	160	2.6	7.9	5.76	7.4	0.2	0.152	125	120	56	143	7.9	0.46	310	646

Table 4-3. Comparison of COCs Concentration in Monitoring Wells in 2012 and 2016

Well	Carbon Tetrachloride		Hexavalent Chromium		Chromium		Iodine-129		Nitrate		Technetium-99		Trichloroethene		Tritium	
	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016
W15-7	580	163	2	1.5	10.6	6.8	0.22	0.85	60.6	102	78	142	1	0.3	1000	747
W15-763	390	310	4	8.6	17.1	107.7	0.2	0.266	474	121.5	890	108	3.7	1.3	13000	2750
W15-765	2233	64	31.1	4.2	35.7	5.6	0.46	0.88	143	38.75	6300	54	6	0.52	4600	549
W15-83	13	35.5	7.5	5.8	14	6.4	0.2	0.481	127	88.6	250	133	0.25	0.205	2300	666
W15-94	20	15.7	7.2	8.3	19.4	8	0.2	0.809	120	106.5	260	196	0.25	0.25	1400	580
W18-1	13	4.3	4.7	6.6	10.5	8	0.36	0.68	117	62	220	101	0.25	0.25	940	1190
W18-16	150	33	6.4	12.3	11.2	11.2	0.2	0.25	540	575	200	234	0.25	0.25	1200	814
W5-2	232	232	95	95	95	76.8	0.87	0.867	606.4	606.4	461.1	461.1	1	1.03	3802	3802
W6-3	0.21	0.13	9.3	9.2	14.6	20.2	0.2	0.16	214	243	47	61.7	0.25	0.25	280	289
W6-6	0.12	0.3	2	2.56	5.47	26.7	0.2	0.578	26	18.1	7	80.3	0.25	0.3	290	2390
W7-3	0.35	0.13	2	4.6	10.9	20.6	0.2	0.842	7	8.175	7	9.5	0.25	0.25	290	165
43-69	580	210	37.7	24	84.2	81	0.2	0.346	31.8	31.9	7	9.75	3	2.4	310	309
44-64	7.9	13	5.8	7.3	8.5	12.8	0.2	0.234	68.2	53.1	70	40.9	2.6	2.3	450	302
45-69A	7.2	0.56	2	8.2	8.8	33.9	0.2	0.54	36	48.7	59	9.24	1	0.25	3100	279
45-69C	39	28	25	27	2.05	31	0.2	0.494	190	217	18	39.9	0.25	0.25	300	299
47-60	0.13	0.3	9	5.54	20.9	48.7	0.2	0.401	36.5	42.5	10.1	10.6	0.25	0.3	270	322
48-71	100	190	59.5	85	108	325	0.78	0.599	374	336	270	196	0.45	1.2	1500	3040
50-74	0.12	0.18	2.9	4.5	6.75	7.3	0.2	0.318	9.03	7.08	6	9.51	0.25	0.25	340	359
51-63	0.12	0.3	2	1.6	1.39	2.5	0.2	0.348	23.2	24.3	6.5	11.4	0.25	0.3	300	105
W14-71	790	801											8.2	12.9		
W15-37	110	157											0.37	0.37		
W18-15	61	18.3											0.625	0.3		
W18-21	0.77	0.33											0.25	0.3		
W18-22	1.1	1.2											0.625	0.25		
W18-40	150	98.3											0.31	0.3		
W19-105	100	40											0.68	0.3		
W19-107	190	150											2.6	5		
W19-18	18	0.13											0.25	0.25		
W19-34A	190	91.3											3.2	1.84		

Table 4-3. Comparison of COCs Concentration in Monitoring Wells in 2012 and 2016

Well	Carbon Tetrachloride		Hexavalent Chromium		Chromium		Iodine-129		Nitrate		Technetium-99		Trichloroethene		Tritium	
	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016
W19-34B	740	106											4.2	4.86		
W19-36	170	12											3.4	1.2		
W19-4	86	48											0.87	0.77		
W19-41	130	150											0.3	0.36		
W19-47	290	126											0.53	0.34		
W19-48	140	22											0.75	0.25		
W19-49	790	305											0.78	0.74		
W19-6	37	53											1.1	1.3		
W21-2	25	29.4											0.655	0.37		
W22-47	110	128											0.25	0.3		
W22-72	22.7	69.4											0.75	0.3		
W22-86	92	16.3											0.75	0.3		
W22-87	18	15											1	0.25		
W22-88	4.7	11.3											0.25	0.65		
W23-19	84	84.4											1	0.3		
W23-4	140	63											0.625	0.25		
W26-13	1	0.59											1	0.3		
W27-2	3.9	5.1											0.25	0.3		
30-66	1.2	0.5											1	0.25		
32-62	3.3	0.13											1	0.25		
32-72A	0.68	0.78											0.25	0.3		
33-75	20	6.25											1	0.21		
34-61	0.45	0.79											0.25	0.3		
35-66A	5	0.96											5	0.32		
35-78A	14	33.2											1	0.3		
36-61A	0.45	0.18											0.25	0.25		
36-66B	2	3.35											5	0.3		
36-70A	4.51	3.62											5	0.27		
36-70B	12	12.2											1	0.3		

Table 4-3. Comparison of COCs Concentration in Monitoring Wells in 2012 and 2016

Well	Carbon Tetrachloride		Hexavalent Chromium		Chromium		Iodine-129		Nitrate		Technetium-99		Trichloroethene		Tritium	
	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016	2012	2016
37-66	1.21	2											5	0.3		
38-61	0.2	0.13											0.25	0.25		
38-65	0.97	1.04											0.27	0.3		
38-68A	8.9	7.6											0.9	0.95		
38-70B	490	173											6	8.15		
38-70C	20	15											3.6	3.1		
40-62	0.2	0.6											0.5	0.38		
40-65	3.1	7.26											1.9	3.25		

Concentration increased

Concentration decreased

Concentration stable

Table 4-4. 200-ZP-1 OU at a Glance

T Plant Operations: 1944 to 1956 (Plutonium Separation) **PFP Operations**: 1949 to 1989			
2016 Groundwater Monitoring			
Contaminant	**Final Cleanup Level**	**Maximum Concentration**	**Plume Area [a] (km^2)**
Carbon tetrachloride	3.4 µg/L	2,500 µg/L (299-W6-15)	10.98 [b]
Chromium (trivalent and hexavalent)	100/48 µg/L [c,d]	166/180 µg/L (299-W11-43)	0.79/0.21
Iodine-129	1 pCi/L	1.20 pCi/L (299-W14-11)	0.09
Nitrate [e]	45 mg/L	708 mg/L (299-W14-16)	7.71
Technetium-99	900 pCi/L	10,700 pCi/L (299-W14-13)	0.04
Trichloroethene	1 µg/L	14 µg/L (299-W14-72)	2.88
Tritium	20,000 pCi/L	58,800 pCi/L (699-48-77D)	0.16

References: EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*.

EPA et al., 2011, *Record of Decision Hanford 200 Area Superfund Site 200-CW5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*.

EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*.

a. Estimated area above listed water quality standard.

b. Area of full plume footprint, all depths in unconfined aquifer.

c. 100 µg/L federal drinking water standard for total chromium.

d. 48 µg/L groundwater cleanup standard for hexavalent chromium.

e. Nitrate as nitrate; 10 mg/L nitrate as nitrogen.

Nitrate (as Nitrate). Nitrate concentrations are above the cleanup standard (10 mg/L as nitrogen; 45 mg/L as nitrate) beneath much of the 200-ZP-1 OU. There is little change from 2015 to 2016 in the interpreted extent and area of the nitrate plume of concentrations over 45 mg/L for the 200-ZP-1 OU (Figure 4-18). Sources of nitrate include liquid waste disposal from PFP processes to the cribs near WMA T and the 216-Z Cribs and Trenches. Three discrete, high-concentration plumes are discernible (Figure 4-18): a plume located beneath WMA T and WMA TX-TY, a plume observed at 299-W18-16 (near the 216-Z Cribs and Trenches), and a plume beneath 299-W5-2. The high concentration for 299-W5-2 was identified when discrete sampling was performed during drilling in 2015. No sampling was performed in 2016. These plumes merge above the 45 mg/L contour extending from the 216-Z Cribs and Trenches to beyond the 200 West Area boundary to the northeast. The high-concentration nitrate plume beneath WMA T, WMA TX-TY, and the 216-Z Cribs and Trenches is located within the extent of hydraulic containment of the 200 West P&T extraction wells. The highest concentration of nitrate for 2016 was 708 mg/L at 299-W14-16 (Table 4-4), which is a *Resource Conservation and Recovery Act of 1976* (RCRA) monitoring well. The large increase in the nitrate concentration in this well is attributed to the shifting in the nitrate plume as a result of the hydraulic influence from the 200 West P&T. Well 299-W5-2 had a 2015 concentration of 735 mg/L and was not sampled in 2016.

Figure 4-19 illustrates changes in the 2012 and 2016 nitrate concentrations in 200-ZP-1 OU monitoring wells. Fifteen monitoring wells had decreasing concentrations, six had increasing concentrations, and 27 had concentrations about the same (less than a 20% difference in concentration) as reported in 2012. Of the six wells with increasing concentrations, two are located near extraction wells drawing in contaminated groundwater. The remaining four wells had increasing concentrations due to plume migration. Figure 4-20 represents a comparison of nitrate concentrations in relationship to the extraction wells. Table 4-3 highlights a comparison of the monitoring wells with increasing or decreasing concentrations, and those wells with concentrations remaining stable for nitrate in 2016.

Technetium-99. Sources of technetium-99 contamination in the 200-ZP-1 OU were releases from past leaks in SSTs and pipelines in WMA T and WMA TX-TY, as well as liquid waste disposal from plutonium-processing operations to cribs and trenches adjacent to the WMAs. Figure 4-21 shows two distinct technetium-99 plumes above the 900 pCi/L cleanup standard centered at the north end of WMA TX-TY and beneath WMA T. The highest concentration was 10,700 pCi/L in monitoring well 299-W14-13, located east (downgradient) of WMA TX-TY. The technetium-99 plumes are migrating eastward as other contaminant plumes in the OU and are within the capture zones of the 200 West P&T extraction wells. Technetium-99 exceeded the 900 pCi/L cleanup standard at three monitoring wells in the 200-ZP-1 OU in 2016 (Figure 4-22). In addition, the increasing trends in these wells between 2012 and 2016 appear to have reversed and are showing declines in 2016. Figure 4-23 represents a comparison of technetium-99 concentrations in relationship to the extraction wells. Table 4-3 highlights a comparison of the monitoring wells with increasing or decreasing concentrations, and those wells with concentrations remaining stable for technetium-99 in 2016. Technetium-99 concentrations declined in most of the monitoring wells in the 200-ZP-1 OU between 2012 and 2016.

Trichloroethene. TCE in the 200-ZP-1 OU is detected at levels above the cleanup standard (1 µg/L) throughout most of the OU and is collocated with the high-concentration portion of the carbon tetrachloride plume (Figure 4-24). TCE contamination is found from the water table to the bottom of the aquifer. The maximum TCE concentration reported during 2016 was 14 µg/L in 299-W14-72, which is a 122% increase from the 2012 concentration of 6.3 µg/L. The increase in concentration is because the well is near an extraction well, which is drawing in contaminated water from surrounding areas. The highest TCE concentrations in other wells were found in 299-W14-71 (a 200-UP-1 monitoring well) and extraction well 299-W11-90 at 12.9 and 12.0 µg/L, respectively. TCE concentrations decreased in most of the 200-ZP-1 and 200-UP-1 OU monitoring wells between 2012 and 2016 (Figures 4-25 and 4-27).

For example, 299-W11-33Q decreased from 11.0 µg/L in 2012 to 2.9 µg/L in 2016, 299-W11-43 decreased from 11.0 to 3.4 µg/L, and 299-W15-50 decreased from 7.9 to 0.5 µg/L. The majority of TCE plumes beneath the 200-ZP-1 OU are located within the capture zones of the 200 West P&T extraction wells. TCE exceeded the 1 µg/L cleanup standard at 28 of the 95 monitoring wells in the 200 West Area in 2016, a decrease of 9 wells from the 37 wells above the cleanup level in 2012. Figure 4-26 represents a comparison of trichloroethene concentrations in relationship to the extraction wells. Table 4-3 highlights a comparison of the monitoring wells with increasing or decreasing concentrations, and those wells with concentrations remaining stable for trichlorethene in 2016.

Tritium. Tritium concentrations did not exceed the cleanup standard of 20,000 pCi/L in the 200-ZP-1 OU, except in 699-48-77C and 699-48-77D, which are monitoring wells adjacent to the State-Approved Land Disposal Site (SALDS; Figures 4-28 and 4-29). Active permitted discharges at SALDS are an ongoing source of tritium to groundwater in the 200-ZP-1 OU. Past sources of contamination included liquid wastes from plutonium processing to disposal facilities (including the 216-T-25 Trench) and past leaks from tanks and pipelines adjacent to WMA TX-TY. Excluding the wells near SALDS, the maximum tritium concentration reported in 2016 in the 200-ZP-1 OU was 13,100 pCi/L at 299-W11-90 (an extraction well located downgradient of WMA T and WMA TX-TY; Figure 4-30). Tritium located near WMA T and WMA TX-TY was contained by the 200 West P&T extraction wells.

4.3.2.2 Natural Attenuation Daughter Products and Field Parameters

Passive natural attenuation processes are part of the cleanup remedy, along with the 200 West P&T, to reduce COC concentrations to below cleanup levels. Natural attenuation processes relied upon to reduce COC concentrations include degradation, dispersion, sorption, and radioactive decay (for tritium). As presented in the final 200-ZP-1 ROD (EPA et al., 2008), natural attenuation processes should reduce COC concentrations to acceptable levels in approximately 100 years after the P&T operational period has diminished the mass of the plumes by about 95 percent. Chloroform, dichloromethane, and chloromethane are monitored for the groundwater interest area as degradation products of carbon tetrachloride; vinyl chloride and cis-1,2-dichloroethene are monitored as degradation products of TCE; chloride is monitored to evaluate natural attenuation of chlorinated solvents; and nitrite is monitored to evaluate natural attenuation of nitrate. Table 4-5 presents the average data for the natural attenuation daughter products and the field parameters in the contaminant monitoring well network during 2016. These data, combined with data from previous years' monitoring, are establishing a data set that can be analyzed to describe the baseline concentrations and trends in MNA indicator parameters. Subsequent reports (starting in CY 2017), once about 5 years of data have been collected, will include these trend-based analyses used in combination with parent contaminant data (e.g., carbon tetrachloride, TCE) and groundwater geochemical and hydraulic conditions to describe plume decline, contributions of natural attenuation, and to evaluate progress toward transition from P&T operations to MNA. Collectively, these data will support numerical modeling interpretations of P&T and MNA remedy performance.

Table 4-5. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in the Contaminant Monitoring Well Network in 2016

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	*cis*-1,2-Dichloro-ethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (mg/L)	Oxidation Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity NTU (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W10-1	19,000	5.10	<0.20	<0.15	<0.32	8,250	0.17	197.0	8.17	424	19.1	6.46	<0.10
299-W10-14	11,000	<0.10	<0.08	<0.09	<0.27	3,870	<0.04	119.4	7.86	364	19.7	1.17	<0.08
299-W10-27	24,000	7.80	<0.08	<0.09	<0.27	5,618	<0.04	257.7	8.22	687	19.1	223.15	<0.08
299-W10-30	17,000	0.75	<0.30	<0.30	<1.60	9,953	<0.04	390.8	7.87	396	20.3	1.83	<0.30
299-W10-31	25,000	0.66	<0.08	<0.09	<0.27	9,743	<0.04	347.9	7.66	483	18.8	2.13	<0.08
299-W10-33	6,900	<0.30	<0.30	<0.30	<1.60	140	<0.04	371.5	7.89	337	20.0	0.35	<0.30
299-W11-13	51,000	9.60	<0.08	<0.09	<0.27	11,940	<0.04	167.7	7.85	1,027	16.5	6.48	<0.08
299-W11-18	10,000	6.42	<0.30	<0.30	<1.60	8,170	<0.04	354.0	7.94	549	18.0	293.00	<0.30
299-W11-33Q	18,000	4.30	<0.10	<0.10	<0.27	8,700	<0.04	312.1	8.05	536	19.8	4.63	<0.19
299-W11-43	17,000	4.95	<0.30	<0.30	<1.60	9,580	<0.04	367.0	7.59	1,118	19.2	2.64	<0.30
299-W11-45	16,000	8.50	<0.20	<0.50	<1.40	8,940	<0.04	260.7	7.96	674	18.6	2.70	<0.97
299-W11-47	18,000	10.90	<0.30	<0.30	<1.60	9,480	<0.05	199.0	8.02	678	19.6	2.02	<0.30
299-W11-48	21,700	8.80	<0.40	<0.45	<1.40	10,140	<0.04	361.5	7.83	743	18.3	1.89	<0.40
299-W11-87	45,500	12.00	<0.30	<0.30	<1.60	10,010	<0.04	414.0	7.48	612	19.2	3.40	<0.30
299-W11-88	7,400	0.27	<0.08	<0.09	<0.27	1,360	<0.04	65.4	7.86	398	20.2	0.10	<0.08
299-W13-1	36,000	7.70	<0.08	<0.09	<0.27	10,670	<0.04	351.9	7.66	521	18.4	2.55	<0.08
299-W13-2	*	3.70	<0.08	*	<0.27	8,130	*	*	7.83	458	20.5	3.96	<0.08

Table 4-5. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in the Contaminant Monitoring Well Network in 2016

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	*cis*-1,2-Dichloro-ethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (mg/L)	Oxidation Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity NTU (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W14-11	29,333	6.85	<0.30	<0.38	<1.60	8,605	<0.04	154.4	7.62	1,162	21.5	3.06	<0.25
299-W14-13	35,500	8.40	<0.40	<1.00	<2.70	8,530	<0.04	268.3	7.85	1035	19.9	7.70	<1.90
299-W14-14	28,000	5.60	<0.30	<0.45	2.14	8,815	<0.04	301.6	8.25	576	20.3	1.79	<0.30
299-W14-71	--	14.00	<0.30	<0.30	<1.60	8,180	--	398.3	7.73	389	19.2	3.20	<0.30
299-W14-72	22,000	10.00	10.00	<0.50	<1.40	7,340	<0.04	198.0	7.89	361	19.2	3.91	<0.97
299-W15-11	16,000	1.11	<0.30	<0.30	<1.60	8,280	<0.04	365.4	7.69	482	18.5	0.37	<0.30
299-W15-152	24,500	0.24	<0.10	<0.10	<0.27	8,021	<0.04	330.9	7.67	552	19.4	2.62	<0.19
299-W15-17	11,000	<0.30	<0.30	<0.30	<1.60	7,890	<0.04	233.3	7.78	369	17.5	1.75	<0.30
299-W15-33	16,000	0.93	<0.08	<0.09	<0.27	8,750	<0.04	200.2	7.95	467	19.2	0.84	<0.08
299-W15-37	--	5.25	<0.30	<0.30	<1.60	7,640	--	177.4	8.31	436	21.5	1.21	<0.30
299-W15-42	52,000	3.90	<0.08	<0.09	<0.27	8,670	<0.04	288.4	7.74	672	21.4	0.35	<0.08
299-W15-46	16,000	0.57	<0.08	<0.09	<0.27	8,240	<0.04	335.1	7.82	497	20.0	1.11	<0.08
299-W15-49	23,000	1.17	<0.30	<0.30	<1.60	11,020	<0.04	341.1	7.84	463	19.0	2.67	<0.30
299-W15-50	22,000	2.20	<0.08	<0.09	<0.09	8,580	<0.04	360.0	7.78	566	19.3	0.69	<0.08
299-W15-7	18,000	1.81	<0.30	<0.30	<1.60	7,935	0.09	236.8	7.74	510	20.9	9.49	<0.30
299-W15-763	26,500	3.80	<0.30	<0.15	0.45	8,445	<0.04	217.7	7.97	618	20.5	12.20	<0.10
299-W15-765	23,000	1.50	<0.30	<0.15	<0.32	9,420	<0.04	273.6	7.97	431	19.2	1.17	<0.10

Table 4-5. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in the Contaminant Monitoring Well Network in 2016

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	*cis*-1,2-Dichloro-ethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (mg/L)	Oxidation Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity NTU (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W15-83	17,500	0.61	<0.20	<0.13	0.41	10,026	<0.04	350.0	7.77	505	19.0	1.38	<0.158
299-W15-94	18,000	<0.30	<0.30	<0.30	<1.60	8,705	<0.04	291.2	7.74	539	19.0	0.68	<0.30
299-W18-1	34,000	0.25	<0.08	<0.09	<0.27	8,130	<0.04	307.2	7.63	586	18.9	0.54	<0.08
299-W18-15+	--	0.9	<0.30	<1.00	<1.60	5,220	--	337.4	8.47	350	15.7	4.56	<0.30
299-W18-16	20,000	1.40	<0.08	<0.09	<0.27	12,650	<0.04	361.0	7.73	1,329	20.3	2.64	<0.08
299-W18-21	--	<0.30	<0.30	<0.30	<1.60	6,686	--	199.2	7.97	596	18.0	11.81	<0.30
299-W18-22	--	0.30	<0.08	<0.09	<0.27	7,929	--	212.0	7.72	388	18.9	2.05	<0.08
299-W18-40	--	3.70	<0.30	<0.30	<1.60	10,350	--	361.8	8.04	415	17.1	975.00	<0.30
299-W19-105	--	0.89	<0.30	<0.30	<1.60	8,910	--	364.9	7.54	274	19.3	3.69	<0.30
299-W19-107	--	5.80	<0.10	<0.10	<0.27	10,450	--	238.0	7.86	439	20.8	1.09	<0.19
299-W19-18+	--	<0.1	<0.08	<0.09	<0.27	10,340	--	294.0	9.53	234	16.7	41.70	<0.08
299-W19-34A	--	4.99	<0.30	<0.30	<1.60	9,550	--	367.3	7.57	428	17.8	416.00	<0.30
299-W19-34B	--	10.80	<0.30	<0.30	<1.60	4,680	--	200.0	7.73	349	21.0	1.63	<0.30
299-W19-36	--	7.10	<0.10	<0.10	<0.27	8,020	--	220.6	7.73	1,328	17.2	2.76	<0.19
299-W19-4+	--	1.40	<0.08	<0.09	<0.27	8,260	--	378.0	7.88	656	22.1	18.5	<0.08
299-W19-41	--	6.24	<0.30	<0.30	2.60	8,580	--	418.9	8.32	329	17.8	2.76	<0.30
299-W19-47	--	5.49	<0.30	<0.30	<1.60	8,930	--	365.8	7.77	388	18.2	2.68	<0.30

Table 4-5. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in the Contaminant Monitoring Well Network in 2016

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	*cis*-1,2-Dichloro-ethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (mg/L)	Oxidation Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity NTU (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W19-48	--	0.82	<0.08	<0.09	<0.27	8,775	--	356.8	7.87	321	21.0	3.15	<0.08
299-W19-49	--	4.36	<0.30	<0.30	<1.60	8,825	--	362.3	7.74	388	21.0	2.41	<0.30
299-W19-6	--	4.40	<0.30	<0.30	<1.60	6,410	--	337.2	7.58	284	18.2	9.87	<0.30
299-W21-2	--	1.55	<0.30	<0.30	<1.60	8,040	--	259.9	7.74	438	22.3	21.80	<0.30
299-W22-47	--	3.20	<0.30	<0.30	<1.60	8,060	--	285.0	7.87	258	17.9	1.07	<0.30
299-W22-72	--	4.04	<0.30	<0.30	<1.60	7,230	--	265.7	7.73	335	24.7	3.71	<0.30
299-W22-86	--	1.40	<0.30	<0.30	<1.60	7,300	--	170.1	7.70	305	20.4	0.57	<0.30
299-W22-87	--	0.56	<0.10	<0.10	<0.27	8,950	--	294.0	7.95	272	27.4	4.53	<0.19
299-W22-88	--	1.95	<0.30	<0.30	<1.60	9,120	--	84.1	7.76	384	21.4	35.40	<0.30
299-W23-19	--	2.21	<0.30	<0.30	<1.60	8,083	--	31.8	7.66	480	18.8	3.85	<0.30
299-W23-4	--	1.45	<0.08	<0.09	<0.27	8,760+	--	187.2	7.87	300	16.7	9.98	<0.08
299-W26-13	--	0.42	<0.30	<0.30	<1.60	8,688	--	184.2	7.81	305	18.4	1.88	<0.30
299-W27-2	--	0.72	<0.30	<0.30	<1.60	6,920	--	80.5	7.53	354	17.9	7.43	<0.30
299-W5-2	*	3.86	<0.19	*	1.64	8,057	<0.04	72.8	7.45	1,302	20.5	31.2	<0.19
299-W6-3	7,500	0.83	0.83	<0.09	<0.27	3,970	<0.04	169.8	8.17	740	16.8	3.41	<0.08
299-W6-6	47,000	<0.30	<0.30	<0.30	<1.60	10,530	<0.04	304.0	7.50	653	14.2	7.33	<0.30
299-W7-3	4,150	0.64	<0.08	<0.09	<0.27	5,390	<0.04	152.0	8.12	304	17.3	2.16	<0.08

Table 4-5. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in the Contaminant Monitoring Well Network in 2016

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	*cis*-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (mg/L)	Oxidation Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity NTU (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
699-30-66	--	0.92	<0.08	<0.10	<0.27	7,100	--	386.4	7.72	399	20.8	0.61	<0.19
699-32-62	--	0.63	<0.30	<0.09	<0.27	7,920	--	283.0	8.02	365	19.6	4.89	<0.08
699-32-72A	--	0.69	<0.30	<0.30	<1.60	5,260	--	336.7	8.06	343	20.7	4.72	<0.30
699-33-75	--	0.56	<0.30	<0.30	<1.60	8,100	--	233.0	7.88	283	18.5	1.69	<0.30
699-34-61	--	1.10	<0.30	<0.30	<1.60	8,980	--	201.1	7.78	409	18.5	6.12	<0.30
699-35-66A	--	1.14	<0.30	<0.30	<1.40	6,110	--	326.7	8.00	385	20.7	1.63	<0.30
699-35-78A	--	0.85	<0.30	<0.30	<1.60	6,420	--	246.8	8.02	291	16.7	2.30	<0.30
699-36-61A	--	0.35	<0.10	<0.10	<0.27	8,210	--	400.9	7.83	403	21.4	2.07	<0.19
699-36-66B	--	0.80	<0.30	<0.30	<1.45	7,600	--	323.7	7.79	483	21.3	1.52	<0.30
699-36-70A	--	0.89	<0.30+	<0.30+	<1.16	8,910+	--	144.0+	7.77	373	19.5	8.42	<0.25
699-36-70B	--	3.34	<0.30	<0.30	<1.60	8,320	--	345.9	7.84	506	24.7	18.30	<0.30
699-37-66	--	0.73	<0.30+	<0.30+	<1.40	9,170+	--	322.1+	7.65	625	21.4	1.16	<0.30
699-38-61	--	0.25	<0.08	<0.09	<0.27	7,170	--	375.9	7.59	414	19.7	3.43	<0.08
699-38-65	--	0.49	<0.30	<0.30	<1.60	2,510	--	75.8	7.89	641	22.7	11.60	<0.30
699-38-68A	--	1.80	<0.08	<0.09	<0.27	10,840	--	158.9	8.01	679	16.1	123.00	<0.08
699-38-70B	--	8.32	<0.30	<0.30	<1.60	10,920	--	388.0	7.41	487	20.1	4.51	<0.30
699-38-70C	--	2.10	<0.08	<0.09	<0.27	9,060	--	107.0	7.75	602	21.3	1.10	<0.08

Table 4-5. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in the Contaminant Monitoring Well Network in 2016

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	*cis*-1,2-Dichloro-ethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (mg/L)	Oxidation Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity NTU (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
699-40-62	--	0.25	<0.08	<0.09	<0.27	8,070	--	111.8	7.88	587	20.4	1.20	<0.08
699-40-65	--	1.55	<0.30	<0.30	<1.60	9,290	--	184.2	7.75	742	21.0	0.62	<0.30
699-43-69	29,000	5.20	<0.16	<0.18	<0.54	10,120	<0.04	380.5	7.90	507	20.7	4.93	<0.16
699-44-64	24,000	1.10	<0.08	<0.09	<0.27	7,230	0.04	315.4	7.76	494	21.4	4.09	<0.08
699-45-69A	21,000	0.78	<0.08	<0.09	<0.27	9,280	<0.04	353.0	8.14	446	18.9	4.63	<0.08
699-45-69C	22,000	1.30	<0.08	<0.09	<0.27	9,830	<0.04	369.0	7.82	700	20.5	2.71	<0.08
699-47-60	10,000	<0.30	<0.30	<0.30	<1.60	8,710	<0.04	315.0	8.17	393	18.8	5.84	<0.30
699-48-71	8,800	3.00	<0.08	<0.09	<0.27	9,110	<0.04	222.5	7.85	866	17.8	12.63	<0.08
699-50-74	2,100	0.73	<0.10	<0.10	<0.27	10,030	<0.04	259.9	8.04	292	21.1	0.42	<0.19
699-51-63	14,000	<0.30	<0.30	<0.30	<1.60	7,1830	<0.04	223.7	8.16	381	20.4	1.79	<0.30

Note: The less than symbol (<) indicates that the sample result was below the listed detection limit.

Concentrations are averaged for all sample results collected throughout the year from each monitoring well for each contaminant.

+ = calendar year 2015 data; no data available for 2016

* = no data available for 2016

-- = analyses not scheduled in 2016

4.3.3 Summary of Contaminant Monitoring Data

Concentrations of carbon tetrachloride are declining due to remediation activities (Figure 4-9). Analysis of the interim system capture zone indicates that the system contained the high-concentration portion of the carbon tetrachloride plume (greater than 2,000 µg/L) present in the upper 15 m (50 ft) of the aquifer. The areal extent of the high-concentration plume at the water table declined over the lifetime of the interim action P&T system by 99%, from 530,000 m^2 (5,704,873 ft^2) in 1996 to near zero in 2014. The highest carbon tetrachloride concentration in 2016 (2,500 µg/L) was found in 299-W6-15 (an extraction well). All 200-ZP-1 and 200-UP-1 OU monitoring wells, except 299-W11-87 (with a maximum concentration of 2,315 µg/L), had carbon tetrachloride concentrations less than 2,000 µg/L. The 200 West P&T is designed to capture and contain the carbon tetrachloride contamination throughout the aquifer that lies beneath the 200-ZP-1 OU, not just the upper 15 m (50 ft) of the aquifer.

The highest concentration of nitrate in 2016 was 708 mg/L at 299-W14-16 (Table 4-4). This was an 800% increase since 2012. The increase in nitrate concentration is likely due to shifting of the regional nitrate plume and changes in groundwater flow in the area as this well is located near extraction well 299-W14-20. Nitrate concentrations in 200-ZP-1 OU monitoring wells are declining in most wells indicating good progress in remediating the plumes.

Since August 2012, extraction well 299-W14-20 has been operating at about 379 L/min (100 gpm). The high flow rate in this well directs groundwater flow eastward, effectively capturing contamination beneath WMA TX-TY. In 2015, technetium-99 concentrations increased nearly four times the concentrations detected in 2012 in two monitoring wells downgradient of WMA TX-TY because these two wells are located near 299-W14-20. In 299-W14-13, technetium-99 concentrations increased from 5,900 to 20,500 pCi/L; in 299-W14-11 from 3,500 pCi/L; and in 2012 to 19,100 pCi/L in 2015. Concentrations in 299-W14-20 also increased from a maximum of 1,241 pCi/L in 2012 to a maximum of 2,450 pCi/L in 2015. In 2016, however, maximum technetium-99 concentrations declined by nearly one-half of the 2015 concentrations to 10,700 pCi/L in 299-W14-13, to 9,500 pCi/L in 299-W14-11, and to 1,390 pCi/L in 299-W14-20, indicating technetium-99 contamination is being removed.

In 2016, TCE concentrations in 200-ZP-1 wells declined an average of 30% since 2012 because of 200 West P&T remediation activities. The TCE contaminant plume extent increased since 2012, which was evident based on sample data from the entire aquifer (not just the upper 15 m [50 ft]) and sample data collected during drilling of new wells in the eastern portion of the 200-ZP-1 OU that were used to delineate the plume.

Tritium concentrations at wells in the 200-ZP-1 OU are declining, from a maximum of 2,940,000 pCi/L in 2000 to 13,100 pCi/L in 2016, which is a 99% decrease in 15 years. This suggests that less contamination is moving from the vadose zone to groundwater. The plume area northeast of WMA T has decreased based on declining concentrations in wells downgradient of WMA T. The decline in tritium concentrations is due to diffusion, migration, and its short half-life and natural radioactive decay.

4.3.3.1 Evaluation of Carbon Tetrachloride Plume Boundaries

From 1996 to 2012, the interim 200-ZP-1 P&T system maintained hydraulic control over large portions of the shallow, near-source, high-concentration areas of carbon tetrachloride. The number of extraction and monitoring wells exceeding carbon tetrachloride concentrations of 4,000 µg/L declined from 20 wells in 1996 to zero wells in 2012. Carbon tetrachloride concentrations in extraction and monitoring wells exceeded 2,000 µg/L in two wells in 2016. Historical carbon tetrachloride plume maps depicting the gradual elimination (between 1995 and 2004) of the greater than 4,000 µg/L area around the PFP are provided in DOE/RL-2013-14. As a result of using sample data throughout the entire thickness of the

aquifer, the estimated extent of the carbon tetrachloride plume above the 3.4 µg/L cleanup level was revised, from about 10.8 km^2 (4.2 mi^2) in 2010 to 14.0 km^2 (5.4 mi^2) in 2011.

Continued investigations during drilling of new groundwater extraction and injection wells in support of the 200 West P&T revealed carbon tetrachloride concentrations greater than 1,000 µg/L throughout the entire thickness of the aquifer rather than just the upper 15 m (50 ft). Figure 4-8 shows the approximate carbon tetrachloride footprint (inset a) above the RLM and (inset b) below the RLM, as derived from the 3D distribution that was prepared for use as initial conditions in the groundwater contaminant fate and transport modeling (see Section 4.3.4 for explanation). The plume map shows carbon tetrachloride extending to the east, north, and south from the source areas. With new extraction wells installed across the 200-ZP-1 OU and screened throughout the unconfined aquifer, and the injection wells installed upgradient (to direct the flow toward the extraction wells) and downgradient (to provide hydraulic gradients that will contain the identified contaminants to the 200 West Area), the vast majority of contaminants within the footprint defined by concentrations of carbon tetrachloride greater than 100 µg/L will be hydraulically contained and ultimately captured by the 200 West P&T. Over time, groundwater remedy optimization activities will be conducted to accelerate attainment of RAOs placing emphasis on increasing mass recovery while maintaining hydraulic capture and flow-path control.

4.3.3.2 Contaminant Plume Cross Section

Figure 4-32 provides a cross-section through a 3D conceptual model of the 2015 carbon tetrachloride plume. The data supporting this figure were derived from groundwater samples collected in 2015 during drilling of new 200 West Area wells screened above the basalt within the unconfined and confined aquifer along the transect. Figure 4-32 shows the carbon tetrachloride plume extending to the east and vertically, downward from the source areas.

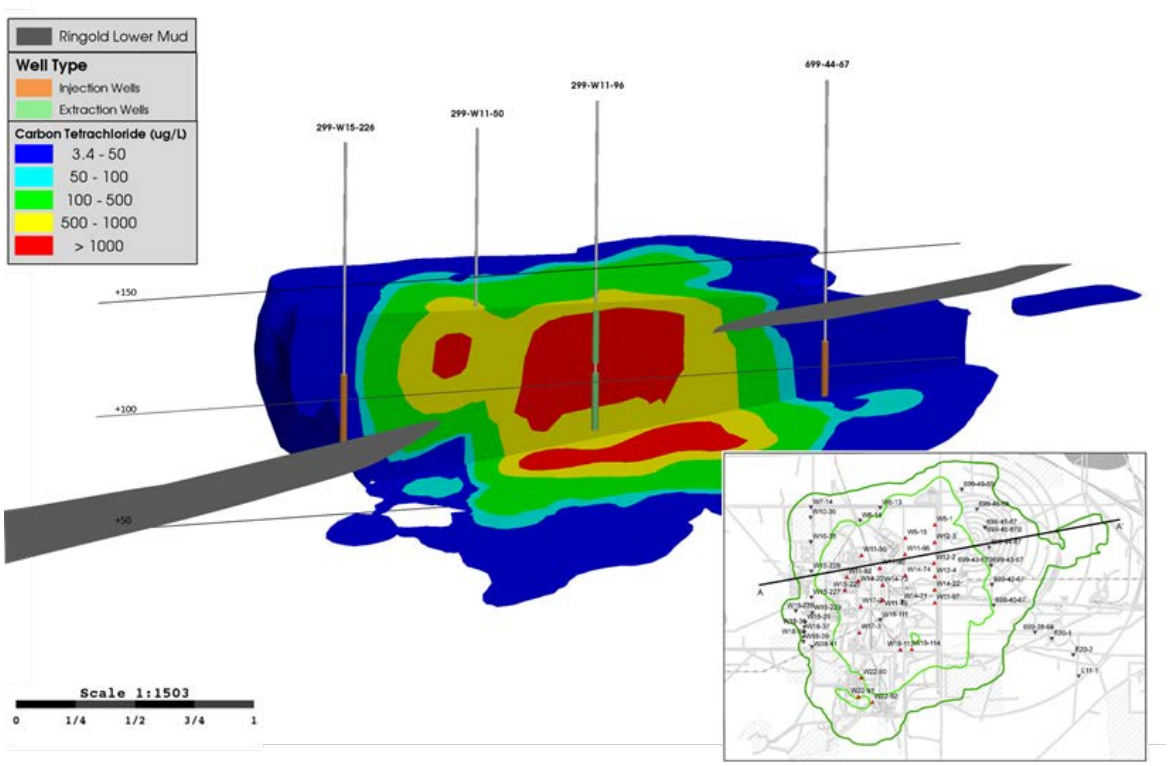

Figure 4-32. 200-ZP-1 OU Carbon Tetrachloride Plume Cross Section A to A'

4.3.3.3 Downgradient Plume Characterization

Drilling of new injection wells downgradient of sources since 2009 revealed the presence of carbon tetrachloride beneath the RLM and into the lower portion of the aquifer in those areas where the RLM is missing in the stratigraphic sequence (Figure 4-32). Extraction wells have since been drilled and installed to the top of the basalt where the RLM is absent to provide for flow-path control, containment, and capture of contamination that migrated into these deeper parts of the aquifer.

4.3.3.4 Natural Attenuation Rates and Transformation Products

Sampling to provide data to track natural attenuation and transformation products continued in 2016. These data will be compared to future data to determine actual rates of attenuation using empirical trend analysis and an assessment of parent-daughter relationships for each COC, where appropriate.

4.3.3.5 Cyanide Contaminant Monitoring

Cyanide contamination has been observed downgradient from WMA T/TX/TY (Figure 4-33) since 2003. Ferrocyanide was used to form precipitates to bind with (scavenge) cesium-137 and settle out in underground storage tanks. Once the chemicals were added to the tanks settling was allowed to occur over 7 to 10 days, after which, the supernatant was decanted and discharged to the ground via cribs and trenches. Tanks used for the scavenging process in WMA T/TX/TY included tanks T-107, TX-118, TY-101, TY-103, and TY-104.

Total cyanide concentrations have been consistently below the MCL value of 200 ppb, and there was no observed trends at six downgradient wells (299-W10-26, 299-W10-27, 299-W11-41, 299-W14-11, 299-W14-13, and 299-W14-18) until late 2012. However, total cyanide concentrations at three wells have increased significantly at the end of 2016. Total cyanide concentrations at the first two wells now exceed the 200 µg/L MCL for total cyanide (Figure 4-34). The WAC 173-340-705, "Model Toxics Control Act—Cleanup," "Use of Method B," MTCA cleanup value for free cyanide is 4.8 µg/L. Free cyanide concentration measured at these wells were either non detect or were below the analytical practical quantitation limit (PQL) of 10 ppb (Figure 4-33). All total and free cyanide measurements performed were performed for nonfiltered water samples. Future samples at these wells will also be analyzed for total and free cyanide in filtered groundwater. Filtered samples will provide information to understand the nature of cyanide in the area as well as whether filtration can provide a reasonable treatment technology for cyanide.

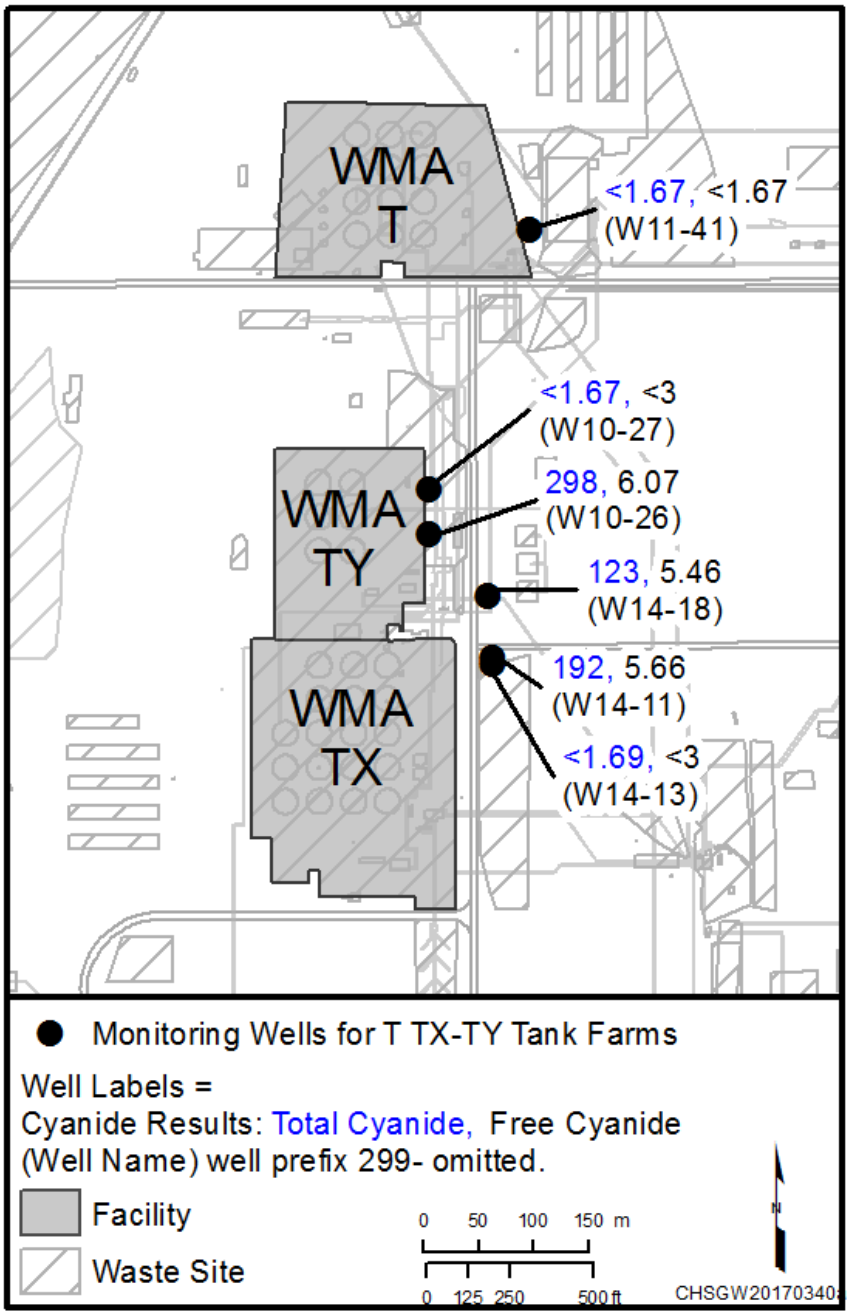

Figure 4-33. Total and Free Cyanide Concentrations Downgradient of WMA T/TX/TY in February 2017

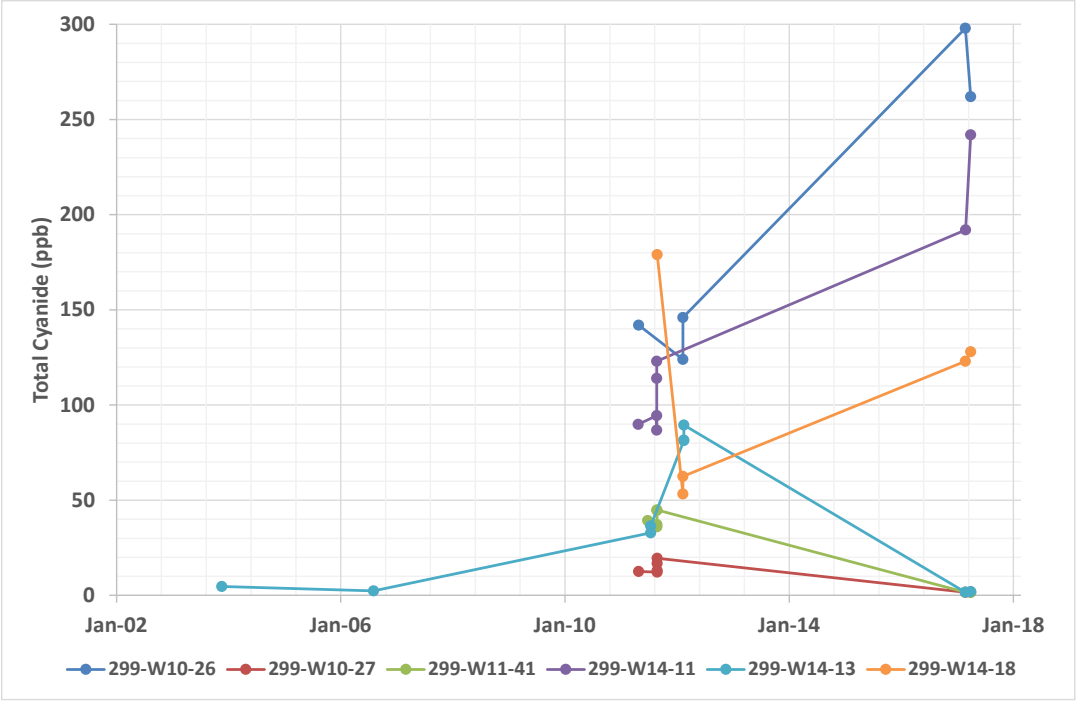

Figure 4-34. Total Cyanide Trends at Wells Downgradient of WMA T/TX/TY

4.3.4 Three-Dimensional Contaminant Plumes

Many calculations performed to design the 200 West P&T remedy and to evaluate and optimize remedy performance rely on 3D depictions of the extent of groundwater contaminated above cleanup levels established in the 200-ZP-1 ROD (EPA et al., 2008) and updated in the RD/RAWP (DOE/RL-2008-78). In particular, sample data are used to construct 3D plume shells as initial conditions for contaminant fate and transport calculations conducted with the CPGWM. The plume shells provide an initial mass for carbon tetrachloride and other COCs for evaluation of attaining mass removal objectives in the 200-ZP-1 ROD. The CPGWM is then used to make projections of the likely effectiveness of the 200 West P&T remedy in achieving the RAOs set forth in the 200-ZP-1 ROD and identify changes to extraction and injection rates that should accelerate attainment of these goals.

Uncertainties associated with defining the extent of contaminants included uncertainty regarding the point sample data, as well as uncertainties regarding the distribution of contaminants between the point sample data and in locations where there are no sample data. Uncertainties regarding the point sample data include variability in analytical methods, low-density spatial coverage of sample data for each contaminant (the most comprehensive coverage is associated with carbon tetrachloride and nitrate), and some wells having long screen lengths (e.g., 45 ft or longer) where samples collected from such a well integrate conditions throughout the intercepted interval.

Uncertainties regarding the spatial distribution of the contaminants between the point sample data, and in locations where there are no sample data, include change in groundwater flow direction over time (primarily due to the changes in wastewater discharges) making it difficult to correlate sample data points spatially. Ideally, sample data could be connected in the direction of groundwater flow. However, the possibility of multiple sources for many contaminants makes it difficult to determine the source origin of the sampled water and contaminants.

During CY 2012, the extent of carbon tetrachloride and other COCs in groundwater within the 200 West Area was mapped in three dimensions using kriging as detailed in ECF-200ZP1-13-0006. Groundwater quality results obtained from sampling of wells in addition to characterization data obtained between CYs 2002 and 2011 were used as input for the mapping to serve as the baseline for performance evaluation. The 3D depictions were updated for the CY 2015 P&T report using data obtained through CY 2015 to provide both the approximate extent of COCs in groundwater and a more current initial condition for modeling purposes summarized in this subsection and detailed in ECF-200ZP1-16-0076, *Description of Groundwater Calculations and Assessments for the Calendar Year 2015 (CY 2015) 200 Areas Pump and Treat Report*. The approximate recent extent of each COC in groundwater was mapped in three dimensions using a combination of kriging and groundwater modeling using the following general steps:

1. The migration of each 3D COC plume mapped in CY 2012 (ECF-200ZP1-13-0006, *Description of Groundwater Modeling Calculations for the Calendar Year 2012 [CY 2012] 200 Areas Pump-and-Treat Report*) and previously used as an initial condition for modeling was simulated using the CPGWM to migrate the depiction of each COC that was prepared in CY 2012 for 3 years (January 2012 through December 2014) to provide an approximate distribution of each COC at the beginning of CY 2015.

2. The average sampled value of each COC obtained from monitoring wells and via characterization data between January 2014 and December 2015 was calculated to represent the best estimate of the COC concentration at each location at the beginning of CY 2015.

3. The difference between the average sample result (Step 2) and corresponding simulated value (Step 1) was calculated. This residual was handled differently for monitoring and extraction wells as follows:

    a. For monitoring wells from which a small volume "point" sample is obtained, the difference was calculated at each monitoring location as the ratio between the average sample result obtained under Step 2 and the simulated value as calculated under Step 1.

    b. For extraction wells, which remove large volumes of water (and as such integrate conditions over a large aquifer volume), the difference was calculated at each extraction well as the ratio between the measured mass recovery during CY 2015 (calculated by multiplying the flow rate by the influent concentration) and the simulated mass recovery obtained under Step 1.

4. The differences calculated in Step 3 represent a 3D scatter of points that depict the relative difference (in terms of a ratio) between expected values based upon the simulated migration of the CY 2012 initial condition over time and the average sampled value between January 2014 and December 2015. This 3D scatter of difference ratios was interpolated using kriging to provide a 3D depiction of the relative difference between the expected (simulated) and measured (sampled) values for each COC throughout 200 West P&T.

5. The 3D relative difference calculated for each COC was then multiplied by the simulated depiction of that COC for December 2014, providing a 3D depiction of the extent of each COC that generally honors the recently sampled values while reflecting patterns in the distribution of each COC that were reflected in the more comprehensive sample data sets available in CY 2012.

To corroborate the resulting depictions for each COC, 3D depictions obtained through the outlined steps were used as initial conditions in the CPGWM for transport simulations commencing at the beginning and continuing through CY 2016. The simulated mass recovery of each COC was then compared with the measured mass recovery over the same period. Improved correspondence was seen between simulated and measured mass recovery using the newly constructed initial condition, versus the previous CY 2012 initial condition, providing confidence in the newly constructed initial conditions.

4.4 Groundwater Flow Model

Application of the CPGWM during CY 2012 for remedy simulation purposes is described in ECF-200ZP1-13-0006, which also provides the calculation methods used to evaluate hydraulic containment and mass recovery; for CY 2016, the process is described in ECF-200W-17-0029. As of CY 2016, the 200 West P&T operated for about 4.5 years; consequently, the system has not operated for sufficient time at design rates to provide a reliable quantitative projection of the likely mass recovery through 2037. ECF-200W-17-0029 demonstrates calculation methods proposed for use after the P&T has been running for a sufficient time for flow rates and hydraulic gradients to stabilize.

This report presents evaluations of hydraulic containment and flow-path control for conditions established in CY 2016. The rates simulated for each 200-ZP-1 extraction and injection well are specified in the model simulations based on rates observed in 2016 presented in Figures 2-4 through 2-7 and Tables 2-2 and 2-3 in Chapter 2. Details of the analyses are included as part of the overall calculation results provided in ECF-200W-17-0029. Simulated mass recovery projections presented therein are based upon assumed operating rates that have not recently been subjected to optimization to maximize mass recovery, and also assume that no difficulties will be encountered with maintaining operating extraction and injection rates that are close to the design rates.

Figure 4-35 depicts groundwater elevation contours computed using the CPGWM for the following aquifer intervals and periods:

- Figure 4-35 (inset a): above RLM at the end of 2016
- Figure 4-35 (inset b): below RLM at the end of 2016

The simulated water table elevations and spacing of contours (equipotentials) compare favorably with the depictions computed using water level mapping (Figure 4-5), particularly within the area of the extraction and injection wells where water level monitoring is abundant. Outside of these areas where the effects of injection and extraction are more subtle with less monitoring density, the mapped and modeled water levels show more notable differences.

Figures 4-36 and 4-37 depict unadjusted and adjusted drawdown and mounding estimated using the CPGWM for the following aquifer intervals (adjustment applied is described in Section 4.2.2.1):

- Figure 4-36 (inset a): above RLM at the end of 2016 (not adjusted for regional water level declines)
- Figure 4-36 (inset b): below RLM at the end of 2016 (not adjusted for regional water level declines)
- Figure 4-37 (inset a): above RLM at the end of 2016 (adjusted for regional water level declines)
- Figure 4-37 (inset b): below RLM at the end of 2016 (adjusted for regional water level declines)

The simulated groundwater mounding/drawdown and spacing of contours above the RLM compares favorably with the depictions obtained via water level mapping (Figure 4-6). In particular, both the mapped and modeled results identify focused areas of drawdown and mounding near the extraction and injection wells, respectively. Near the 200-ZP-1 OU groundwater extraction wells that pump primarily above the RLM, a large area exhibits drawdown that exceeds 1 m (3.3 ft). Two distinct regions of the aquifer that exhibit mounding exceeding 1 m (3.3 ft) are focused around the injection wells screened above the RLM on the west side of the 200-ZP-1 OU and around the injection wells screened beneath the RLM on the east side of the OU. The simulation results are consistent with findings from the water level interpolation, which suggests that the CPGWM reasonably reflects the actual impacts of extraction and reinjection on the aquifer.

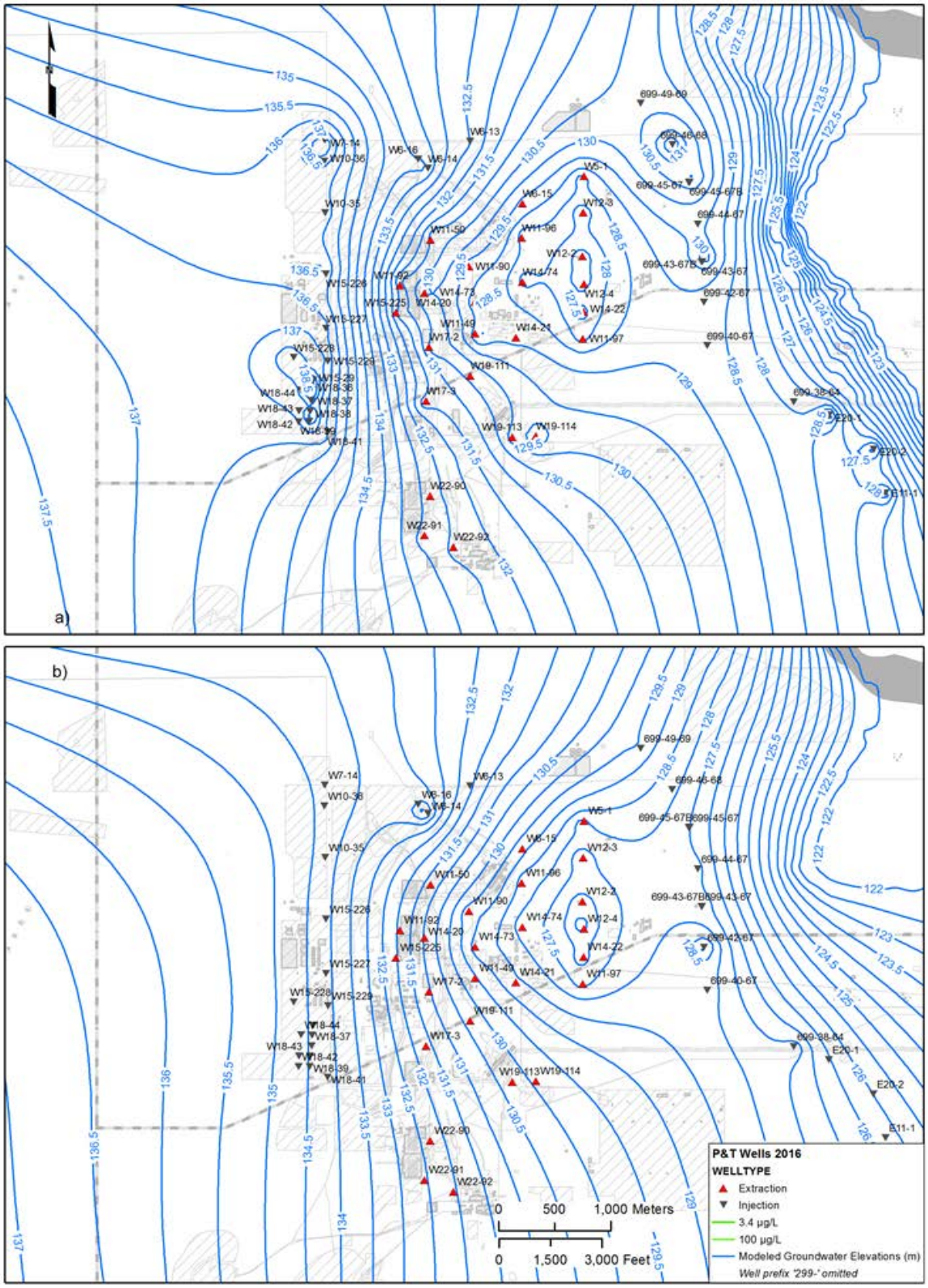

Figure 4-35. Groundwater Elevation Contours Computed Using the CPGWM: (a) Above the RLM at the End of 2016; (b) Below the RLM at the End of 2016

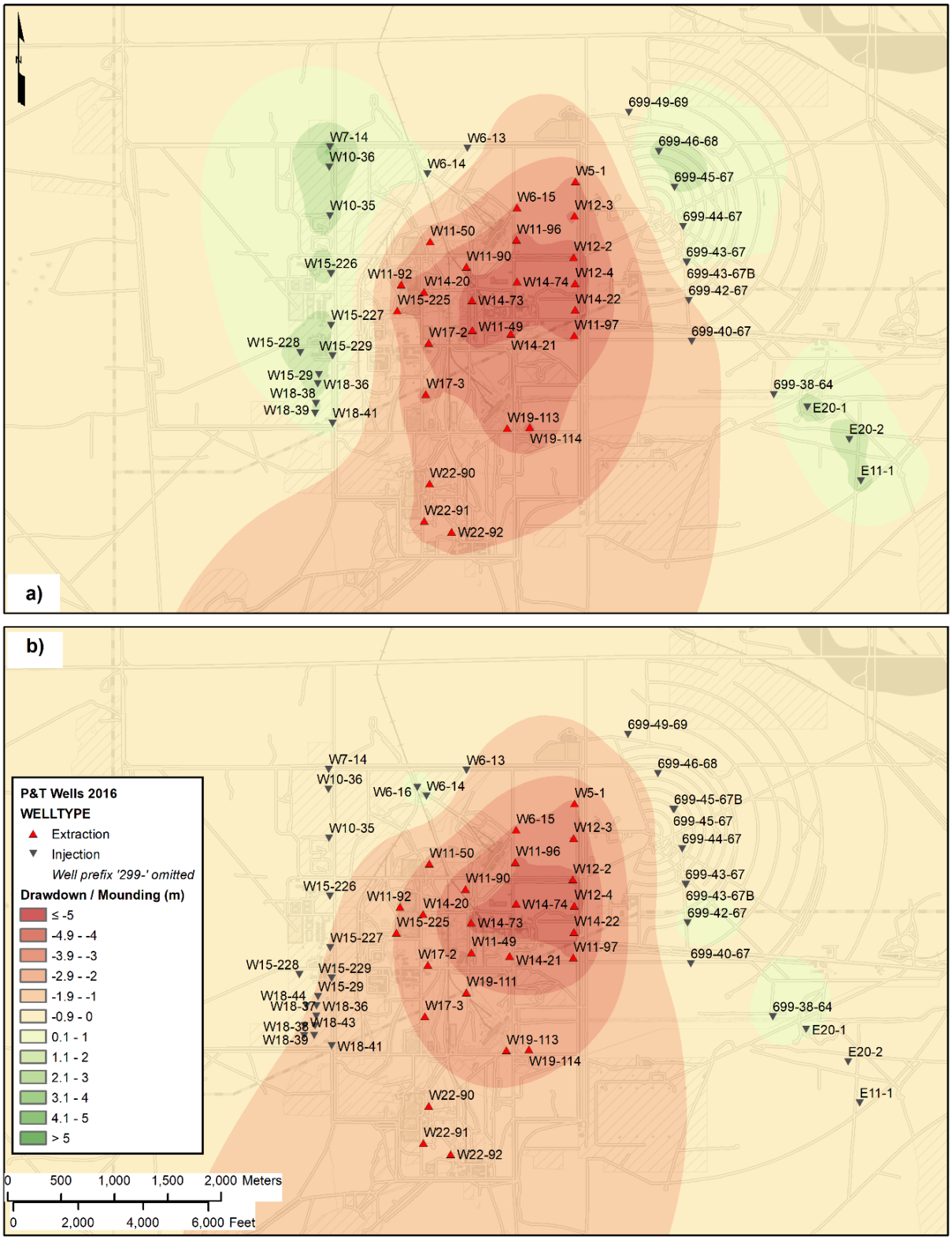

Figure 4-36. Unadjusted Drawdown and Mounding Estimated Using the CPGWM: (a) Unadjusted Drawdown above the RLM at the End of 2016; (b) Unadjusted Drawdown below the RLM at the End of 2016

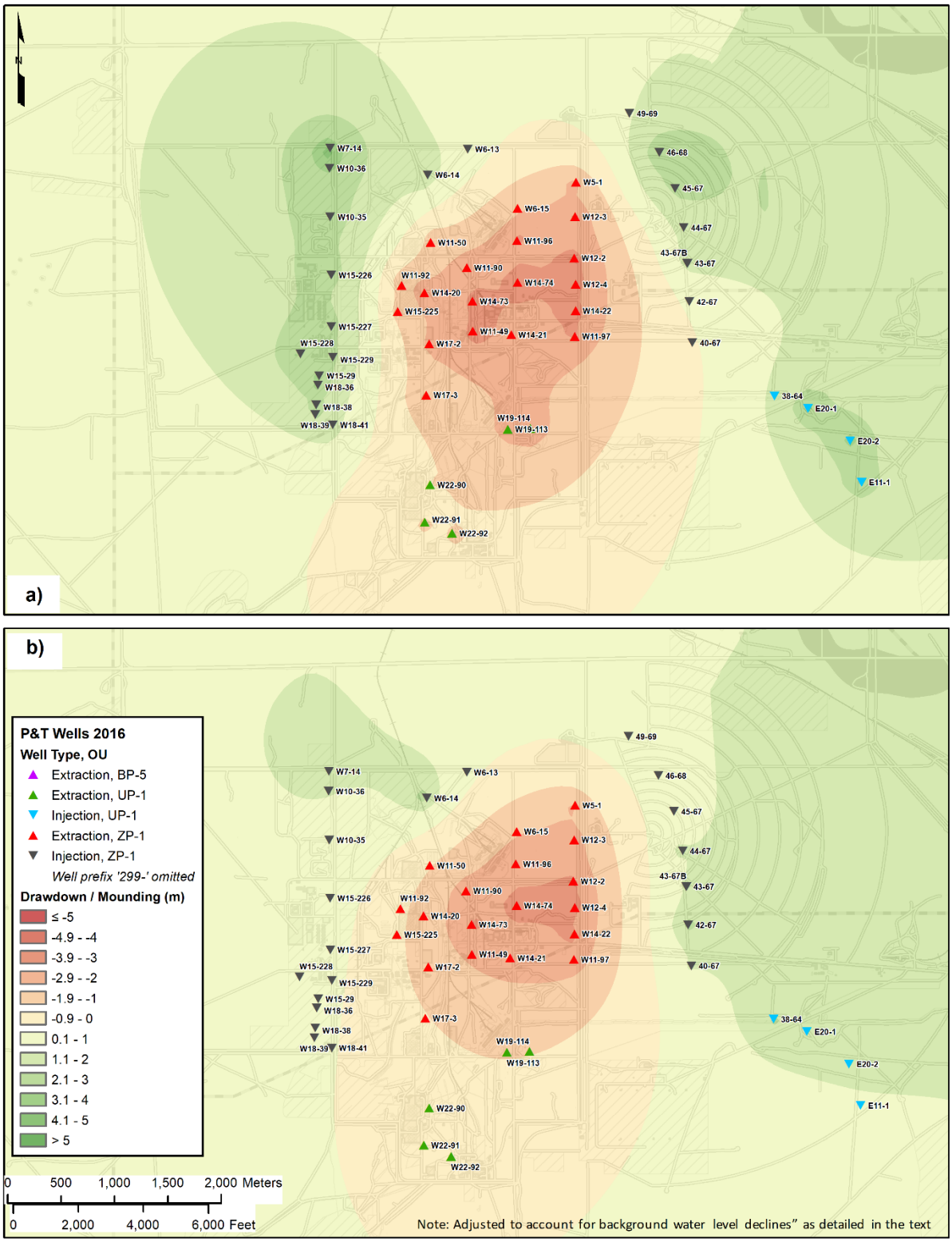

Figure 4-37. Adjusted Drawdown and Mounding Estimated Using the Central Plateau Model: (a) Adjusted Drawdown above the RLM at the End of 2016; (b) Adjusted Drawdown below the RLM at the End of 2016

Figure 4-38 depicts the simulated extent of hydraulic containment for December 2016 above and below the RLM. The extent of containment was computed by releasing particles in cells and every layer of the CPGWM throughout the 200 West Area and then forward tracking them using a low value for mobile porosity, which resulted in a depiction of the instantaneous extent of hydraulic containment. These depictions identify the current focus areas of containment and mass recovery: the extent of hydraulic containment depicted in Figure 4-38 is approaching (but is still smaller than) the size that will be developed by the remedy when it is operating at 7,571 L/min (2,000 gpm).

4.5 Contaminant Transport Modeling

This report describes contaminant transport analyses for conditions since the inception of the 200-ZP-1 P&T remedy through CY 2016 by the 200 West P&T; full details of the calculations are presented in ECF-200W-17-0029. Contaminant transport calculations from the CPGWM are used for the following purposes:

- Comparing simulated mass recovery for each COC with actual (measured) mass recovery, which is presented and discussed in this report section
- Evaluating progress toward the mass recovery goals outlined in the 200-ZP-1 ROD (EPA et al., 2008), which is discussed in Section 4.6

Figures 4-39 and 4-40 plot simulated and measured carbon tetrachloride influent concentrations for the 200 West Area extraction wells since the startup of the system in 2012. Simulated influent concentrations shown in Figure 4-39 assume a 100-year half-life for carbon tetrachloride, whereas those in Figure 4-40 assume a 41-year half-life. Similar figures are presented in ECF-200W-17-0029 for the other 200-ZP-1 OU COCs. In each graph, two simulated concentrations are shown: the first, calculated using the 3D initial conditions developed in CY 2012, and the second, calculated using the 3D initial conditions developed in CY 2015 (the latter simulations commence January 2015). In general, the comparison between simulated and measured concentrations is quite good at most wells, which is encouraging since the transport parameters of the CPGWM have not been calibrated to the water quality data obtained from monitoring and extraction wells since the P&T system began operation.

Figure 4-41 presents the simulated and measured carbon tetrachloride mass recovery for the 200 West P&T since startup of the system in 2012. Simulated mass recovery in Figure 4-41 (inset a) assumes a 100-year half-life for carbon tetrachloride, whereas that in Figure 4-41 (inset b) assumes a 41-year half-life. Similar figures are presented in ECF-200W-17-0029 for the other 200-ZP-1 OU COCs. Comparison of simulated and measured carbon tetrachloride mass recovery indicates that the actual mass recovered by the system slightly exceeds the simulated recovery.

The CPGWM is updated each calendar year to incorporate actual (monthly averaged) extraction and injection rates to minimize differences between actual and simulated flows. As a result, the higher measured mass recovery depicted in Figure 4-41 may indicate that more mass was present in the subsurface than represented in the initial modeled plume; or that one or more transport simulation parameters require calibration to the sample data obtained since the remedy commenced; or a combination of these factors. As additional data become available on system-wide and well-specific mass recovery rates, contaminant transport parameters will be calibrated to improve correspondence between the actual and simulated mass recovery, improving the reliability of longer term mass recovery projections.

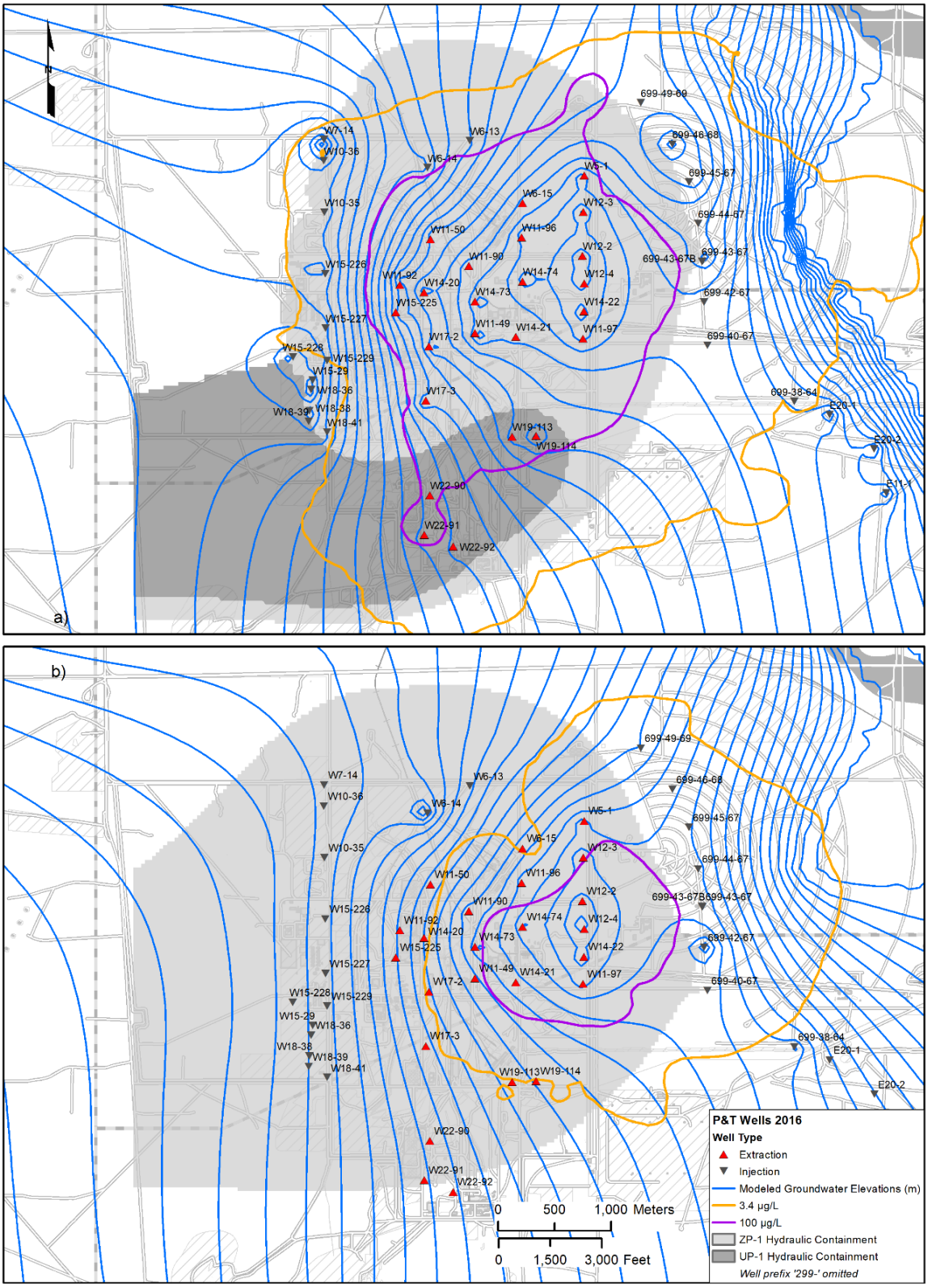

Figure 4-38. Extent of Hydraulic Containment Computed for December 2016 Using the Central Plateau Model: (a) Above the RLM and (b) Below the RLM

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Figure 4-39. Simulated and Measured Carbon Tetrachloride Concentrations at Extraction Wells Assuming a 100-Year Half-Life

Figure 4-40. Simulated and Measured Carbon Tetrachloride Concentrations at Extraction Wells Assuming a 41-Year Half-Life

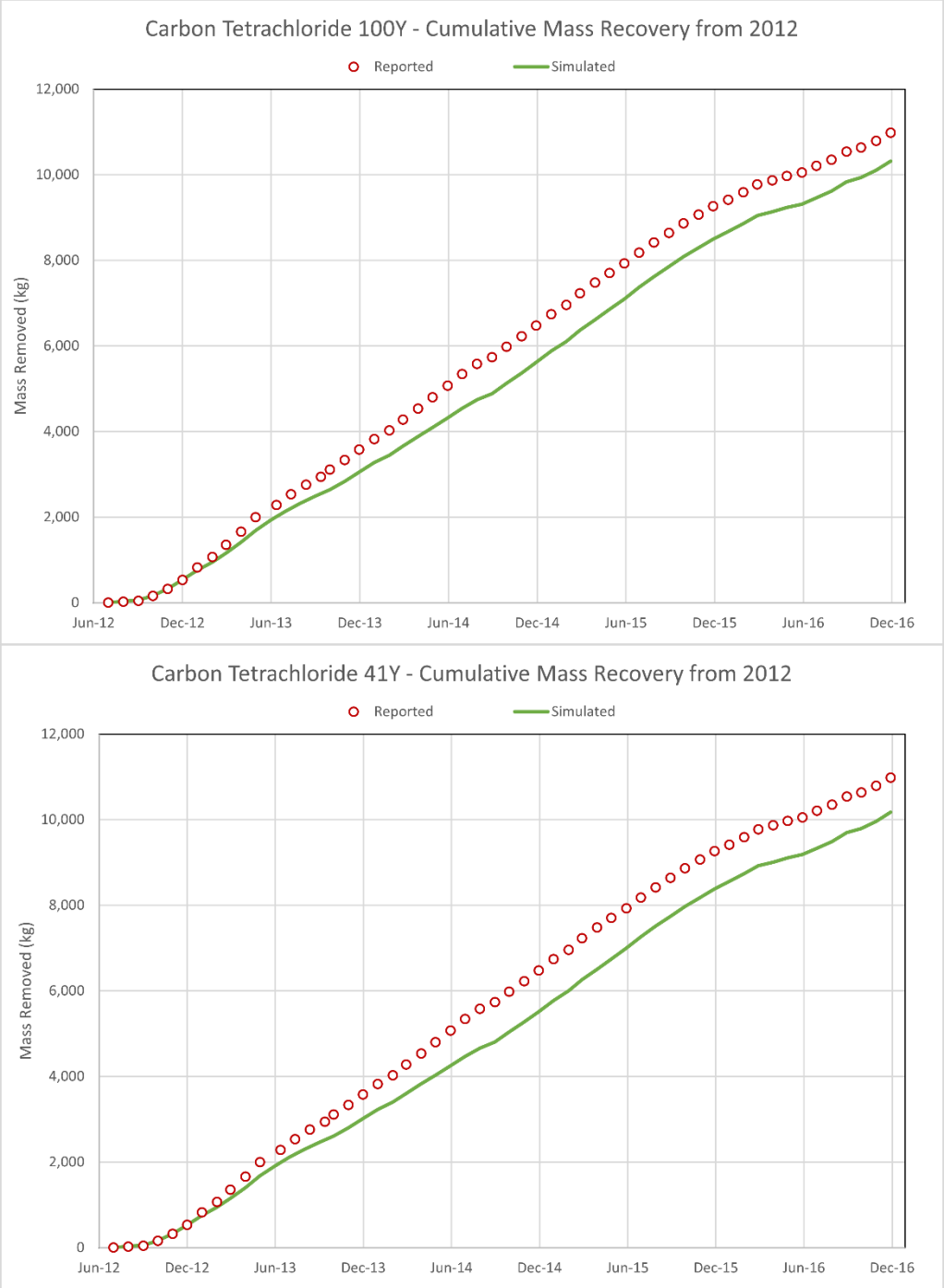


Figure 4-41. Simulated and Measured Carbon Tetrachloride Mass Recovery Assuming (a) 100-Year Half-Life and (b) 41-Year Half-Life

4.6 Progress Toward Meeting Remedial Action Objectives

This section evaluates progress toward attaining the remedy goals and the final RAOs outlined in the 200-ZP-1 ROD (EPA et al., 2008). The following progress for the 200 West P&T is discussed in this section:

- 2012 through 2016 performance of the 200 West P&T component of the remedy in attaining hydraulic containment of carbon tetrachloride concentrations exceeding 100 µg/L
- 2012 through 2016 performance of the 200 West P&T component of the remedy in terms of developing flow-path control throughout the area affected by 200-ZP-1 OU contaminants
- 2012 through 2016 performance of the 200 West P&T component of the remedy in attaining 95% mass removal of carbon tetrachloride

4.6.1 Evaluation of Hydraulic Containment of the 100 µg/L Carbon Tetrachloride Boundary

As described in Section 4.3.1 of the 200-ZP-1 ROD (EPA et al., 2008), the groundwater P&T system is designed to contain, recover, and treat contaminated groundwater. The locations of the extraction and injection wells for the 200 West P&T were selected to encompass the area defined by carbon tetrachloride concentrations exceeding 100 µg/L. Because the majority of contaminant mass lies within this iso-concentration line, focusing hydraulic containment on this area maximizes the efficiency of mass recovery.

Figure 4-38 depicts the extent of hydraulic containment above and below the RLM as computed using the CPGWM, overlaid with a depiction of the extent of carbon tetrachloride in groundwater above concentrations of 3.4 µg/L (the cleanup level) and 100 µg/L (the level targeted for hydraulic containment and focused mass recovery). Figure 4-7 depicts the estimated extent of hydraulic containment above the RLM, as determined through water level mapping, overlaid with the same 3.4 µg/L and 100 µg/L iso-concentration lines. The extent of hydraulic containment depicted in these figures reflects groundwater extraction at a typical rate of about 6,800 L/min (1,800 gpm) for the 200-ZP-1 extraction wells during December 2016, together with additional groundwater recovery by the 200-UP-1 extraction wells, which contributes to the combined extent of hydraulic containment throughout the 200 West Area. Review of these figures indicates that the current focus area of hydraulic containment and mass recovery is in the core area of the groundwater extraction wells, and the region defined by the 100 µg/L concentration was largely contained by pumping in the 200 West Area as of 2016 during months in which sustained pumping approached design rates. The one exception to this is located in the area northeast of the focused groundwater extraction, where concentrations exceeding 100 µg/L appear to extend beyond the zone of hydraulic containment. Nonetheless, the comparison of the extent of containment with the extent of contamination above 100 µg/L suggests that if the P&T can sustain rates close or exceeding design rates, it can produce a region of hydraulic containment that is larger than the area mapped at concentrations above 100 µg/L. Planned rate increases and rebalancing of groundwater extraction and reinjection are anticipated to improve hydraulic containment.

4.6.2 Evaluation of Flow-Path Control

As stated in Section 4.3.3 of the final 200-ZP-1 ROD (EPA et al., 2008):

> *Flow-path control is also required and shall be achieved by injecting the treated groundwater into the aquifer to the northeast and east of the groundwater contamination such that the treated injected water in these locations will slow the natural eastward flow of most of the groundwater and, as a result, keep COCs within the capture zone, as well as increase the time available for natural attenuation processes to reduce the contaminant concentrations not captured by the extraction wells.*

Flow-path control considers the extent of hydraulic containment and the development of reduced hydraulic gradients to the northeast and southeast of the 200-ZP-1 OU. Evaluations for the development of flow-path control integrate assessment of the extent of contamination (emphasizing carbon tetrachloride), the extent of hydraulic containment, and the region over which hydraulic gradients are reduced by operation of the 200 West P&T. Methods used to evaluate and depict the status of flow-path control were first detailed in ECF-200ZP1-15-0002, *Description of Groundwater Modeling Calculations and Assessments of the River Protection Objective for the Calendar Year 2014 (CY 2014) 200 Areas Pump-and-Treat Report*. The methods used were revised in preparation of this CY 2016 annual report to provide visual depictions that are more intuitive and readily interpreted. The methods used in preparation of this CY 2016 annual report are detailed in ECF-200W-17-0029.

Figures 4-42 and 4-43 depict estimated mapped and simulated hydraulic gradients, respectively, above the RLM. Figure 4-44 depicts estimated hydraulic gradient below the RLM. In Figures 4-42 through 4-44 the arrow orientation indicates the gradient direction, and arrow length indicates gradient magnitude. Because natural gradients in this area would be toward the east, the hydraulic gradient absent the groundwater P&T would produce arrows pointing toward the east as depicted in left panel a in each figure. The gradient direction and magnitude under current conditions is depicted by arrow orientation and length in the right panel b in each figure. Larger changes in gradient direction and magnitude due to the P&T are evidenced by larger differences in the arrow direction and length between the a and b panel figures. The greatest gradient magnitude and direction changes are observed between the extraction and injection wells. Gradient magnitude changes are depicted in the right panel b figures by coloring: a decrease in the gradient magnitude from west to east is colored red, whereas an increase in gradient magnitude in the same direction is depicted in green. Gradient changes as expected are less evident moving farther away from the extraction and injection wells to the northeast and southeast of the 200-ZP-1 OU (i.e., to the north and to the south of the eastern [downgradient] line of injection wells). Flow-path control will be evaluated in greater detail after the 200 West P&T has been running at full capacity for a sufficient time to stabilize hydraulic gradients. As of 2016, the 200 West P&T has operated for about 4.5 years, and extraction and injection wells are still being added to bring the system to full capacity.

4.6.3 Evaluation of Contaminant of Concern Mass Removal Goal

As described in Section 4.3.1 of the 200-ZP-1 ROD (EPA et al., 2008), carbon tetrachloride concentrations in the groundwater above 100 µg/L correspond to approximately 95% of the dissolved mass of carbon tetrachloride currently residing in the aquifer. The pumping rate estimated in the FS to reduce the carbon tetrachloride mass by 95% in 25 years is 6,050 L/min (1,600 gpm). To achieve the mass removal objectives of the ROD, a phased implementation approach was identified for the 200-ZP-1 P&T design (DOE/RL-2008-78, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*). The phased implementation approach from the 200-ZP-1 P&T RD/RAWP included an initial 3 year phase with the P&T operating at a nominal rate of 3,785 L/min (1,000 gpm) followed by 22 years of operating at a nominal rate of 7,571 L/min (2,000 gpm).

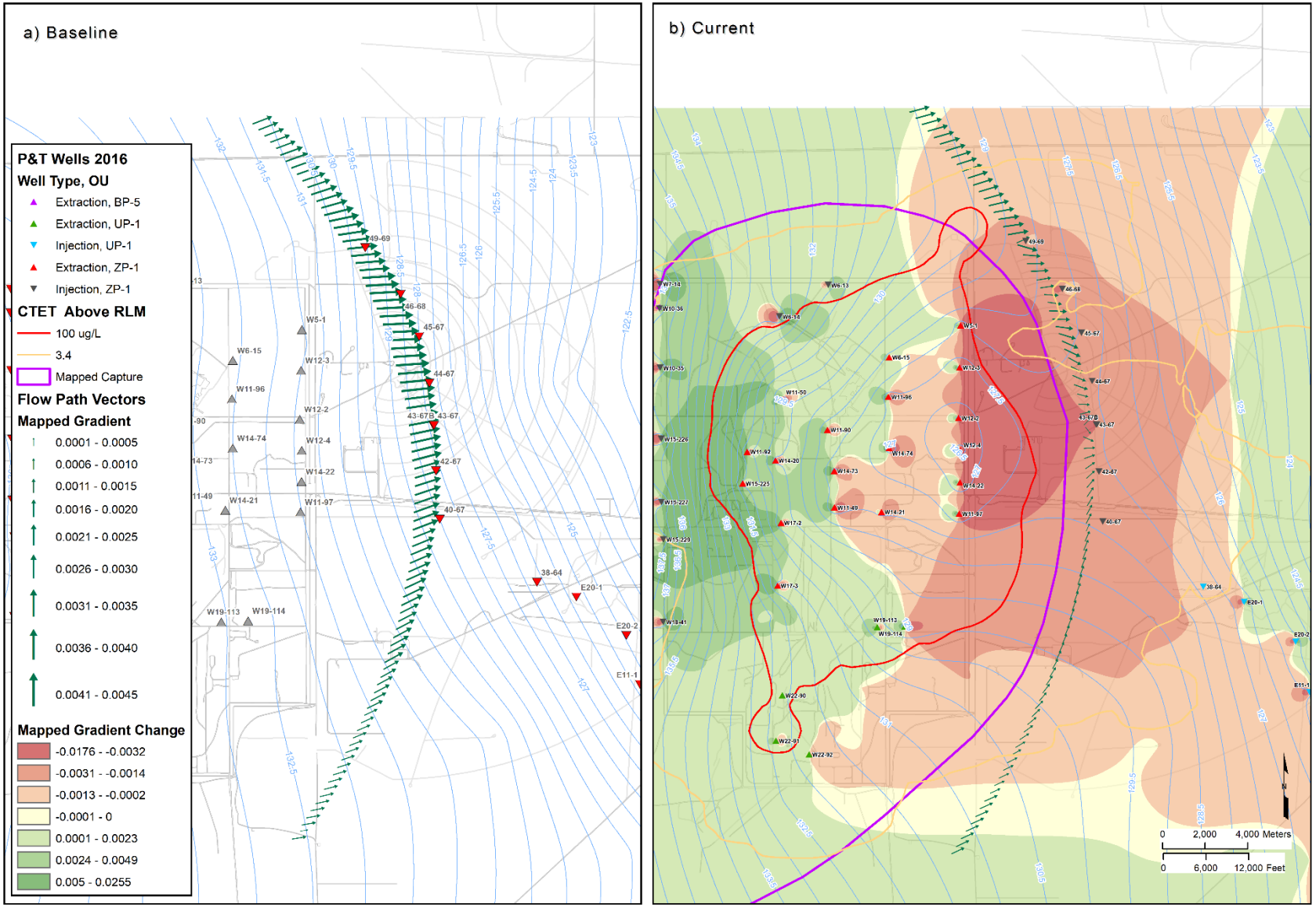


Figure 4-42. Mapped Gradient Changes along Line of Control above the RLM: (a) Baseline and (b) Current

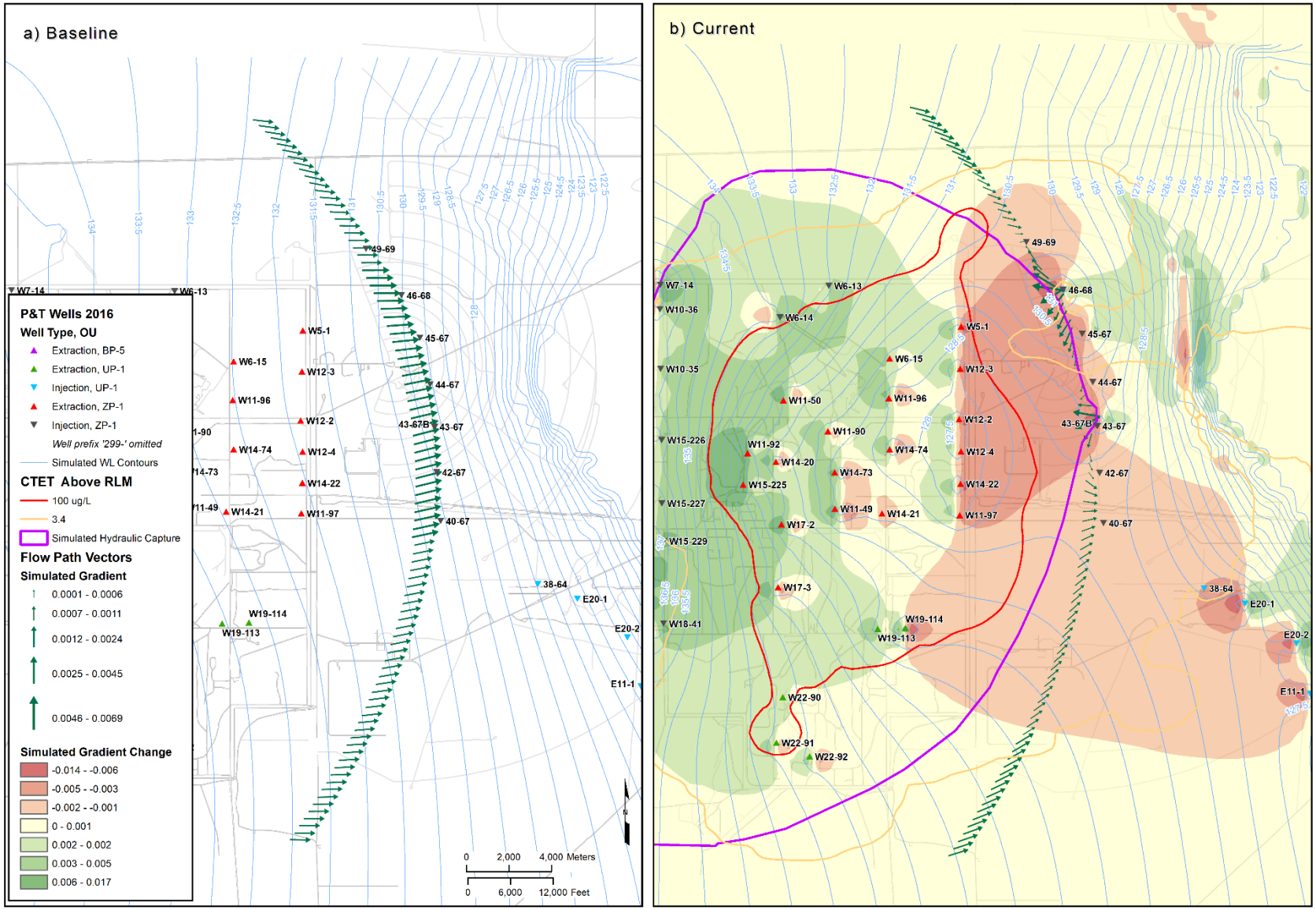


Figure 4-43. Simulated Gradient Changes along Line of Control above the RLM: (a) Baseline and (b) Current

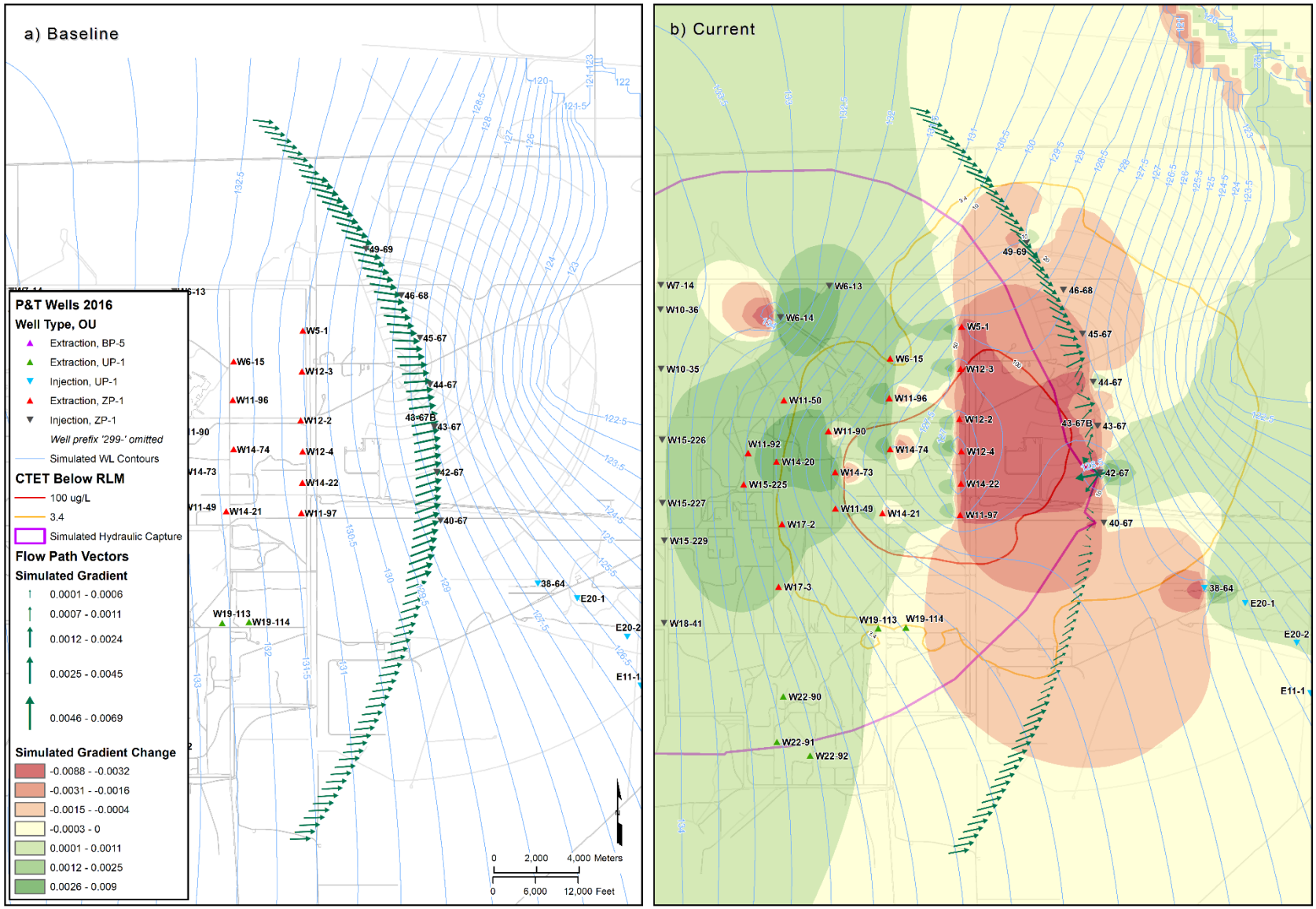


Figure 4-44. Simulated Gradient Changes along Line of Control below the RLM: (a) Baseline and (b) Current

Figure 4-45 shows the volume treated since startup compared to projected volume treated based on the design flow rates. The majority of the treated volume is groundwater extracted from the 200-ZP-1 OU. The 200 West P&T also treats contaminated groundwater from other OUs (e.g., 200-UP-1, 200-DV-1, 200-BP-5) as discussed in Chapter 2 of this report. Through the end of 2016, the cumulative 200-ZP-1 OU extracted groundwater treated is above the projected design throughput. During the last 6 months of 2016 (following repairs to the FBR [see Section 2.2.3]), the combined 200-ZP-1 OU extraction well flow rate averaged 6,282 L/min (1,661 gpm), the average flow rate of the 200-ZP-1 OU and S-SX extraction wells was 6,612 L/min (1,749 gpm), and the total average flow rate from all OUs to the 200 West P&T was 7,446 L/min (1,970 gpm). As discussed in Section 2.2.1, recommendations to minimizing biofouling issues to improve injection well capacity are planned for implementation in 2017. These actions along with ongoing 200 West P&T optimization activities are being conducted to achieve operating at the facility design throughput identified in the RD/RAWP.

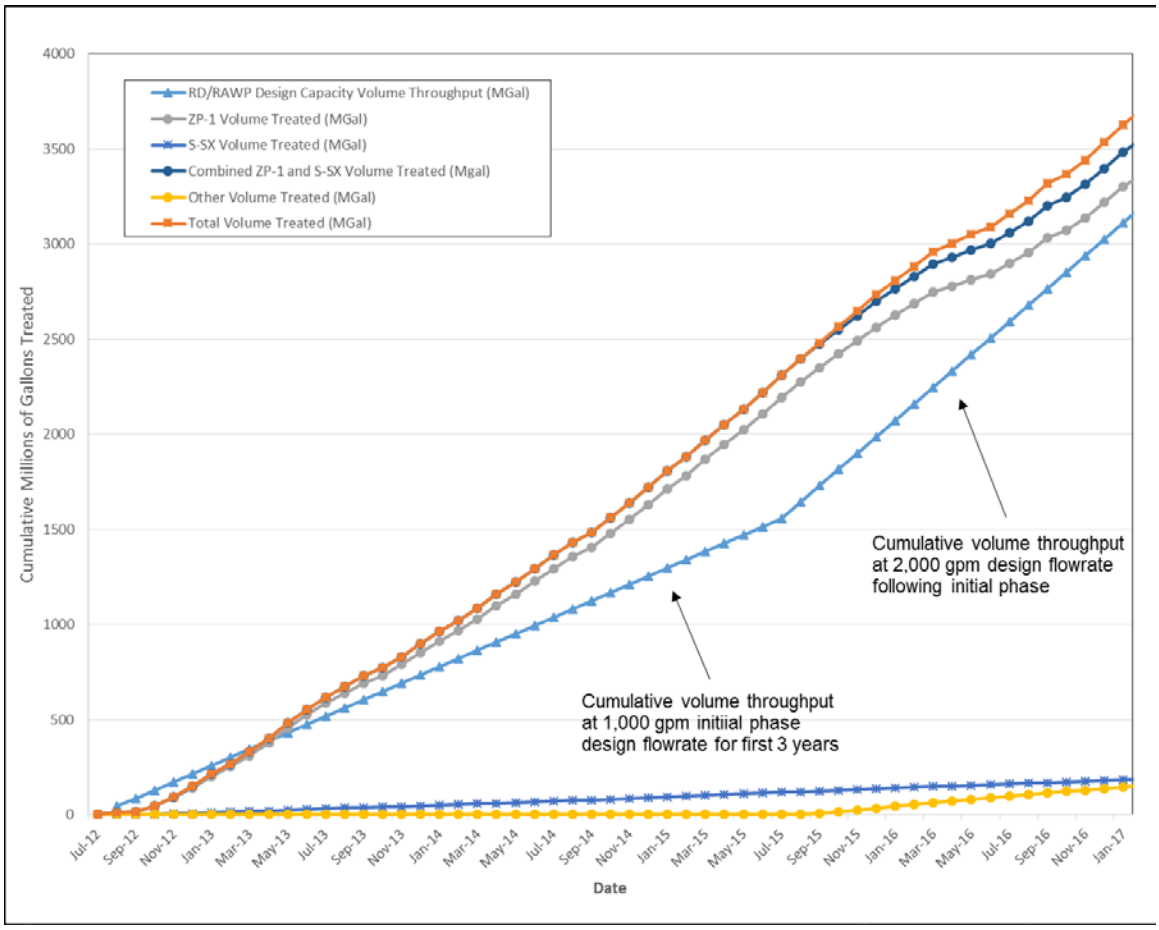


Figure 4-45. 200 West P&T Actual Cumulative Volume Treated Compared to Design Capacity Throughput

As described in Section 4.3.4, the carbon tetrachloride plume shell was updated in 2015 along with the initial mass calculations (ECF-200ZP1-16-0076). The projected mass recovery based on the updated plume shell and initial concentration is depicted in Figure 4-46. The simulated mass removed by extraction over the 25 year P&T period is 79% of the calculated initial mass. Another 18% of the carbon tetrachloride mass is simulated to decay through abiotic degradation based on a 41.3 year half-life for remediation of a total of 97% of the initial mass over the 25 year P&T period.

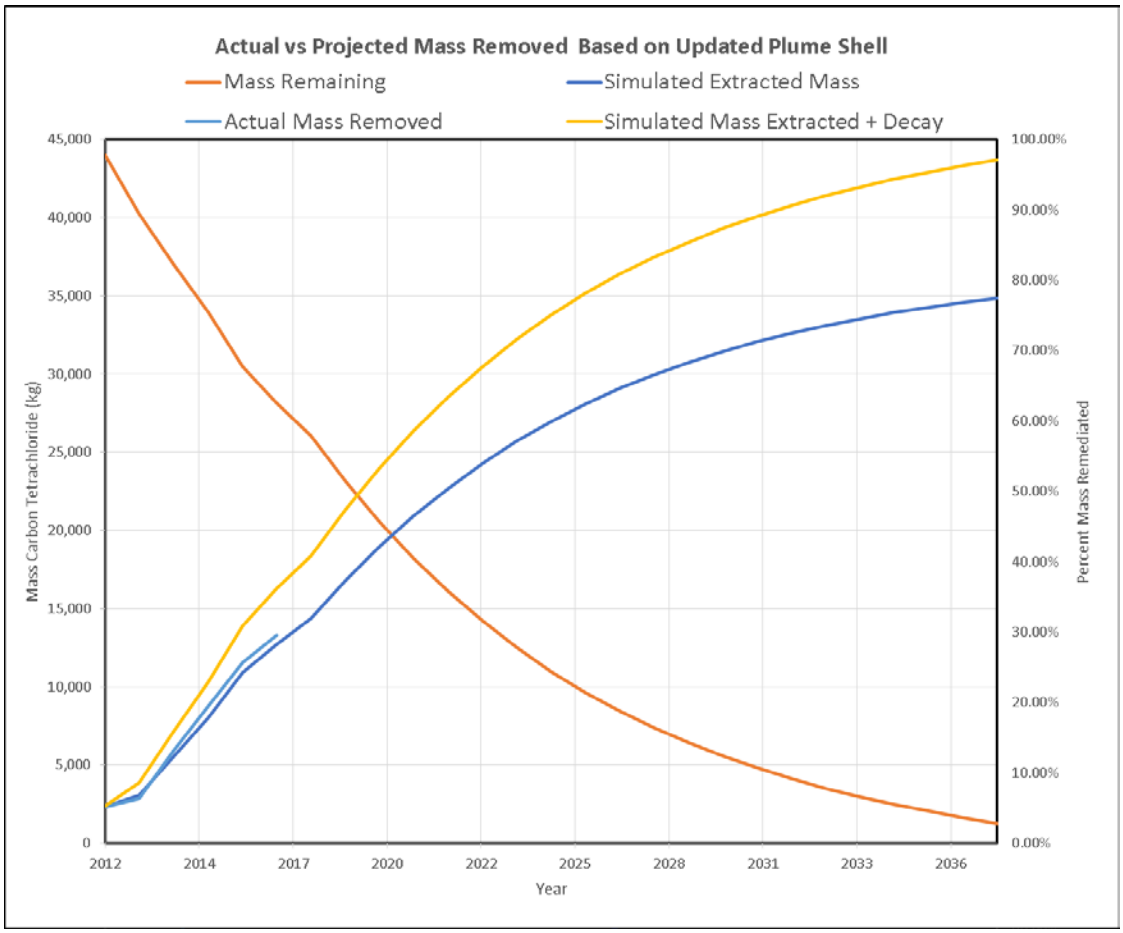


Figure 4-46. Actual Carbon Tetrachloride Mass Recovery Compared to Projected Mass Recovery

Figure 4-46 also shows the actual mass recovery through 2016 from extraction wells. The actual mass recovery corresponds well to the projected mass recovery indicating the updated plume shell correlates well with observed site conditions. The projected to actual mass recovery comparison is based on the transport calculation methods presented in ECF-200ZP1-15-0002. The application of these calculation methods for predictive contaminant transport simulations and comparison of observed to simulated extraction well concentrations and mass removal, are provided in ECF-200W-17-0029.

The comparison of the actual to projected mass removed by the 200 West P&T through 2016 indicates that mass removal targets are being achieved, but attaining the 95% mass removal target is dependent on the estimated initial mass. Table 4-6 presents the estimated mass recovery range recovered in 25 years (i.e., extracted and treated) based on the phased implementation approach identified in DOE/RL-2008-78. The estimates ranged from 57 to 100%, and represent the range in uncertainty in the site conditions, namely associated with the initial dissolved contaminant mass, distribution coefficient (range from 0.01 to 0.06), and porosity (range from 13 to 18%). Groundwater flow and transport modeling supporting the 200-ZP-1 RD/RAWP as documented in DOE/RL-2009-38, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*, identified that contaminant depictions prepared using the ordinary kriging method are considered to be the "best estimate" of the contaminant distribution. As such, the ordinary kriging method used in the plume shell calculations (Section 4.3.3) is considered to provide the best estimate of the carbon tetrachloride initial mass.

The initial mass calculated using the stochastic sequential simulation approach in Table 4-6 present an alternate (and typically considerably higher) potential contaminant distribution, leading to a corresponding upper bound of the initial carbon tetrachloride mass. Figure 4-47 shows the projected carbon tetrachloride mass removal associated with applying the plume shell updating methods and predictive transport simulations to the upper initial mass range in Table 4-6. The simulated total mass removal for the upper initial mass range is 71 percent of the initial mass over the 25 year P&T operating period. Overlaying the mass removal projections from Figures 4-46 and 4-47 provides a range for the projected mass removal associated with the uncertainties in site conditions (Figure 4-48).

Table 4-6. Estimated Recovery of Dissolved-Phase Carbon Tetrachloride Mass in 25 Years (from Table 3-2 of DOE/RL-2008-78)

Run	Initial Condition	K_d	Porosity	Calculated R	Initial Mass (kg)			Mass Extrated (kg)	Mass Decayed (kg)	Mass Remediated (kg)	% Dissolved Mass Remediated at 25 Yr
					Dissolved	Sorbed	Total				
1	Kriging	0.011	0.18	1.105	47,127	4,954	52,080	36,831	4,879	41,710	89%
2	Stochastic	0.011	0.18	1.105	93,553	9,834	103,387	40,738	12,998	53,736	57%
3	Kriging	0.011	0.13	1.146	35,281	3,708	38,990	30,688	3,164	33,852	96%
4	Stochastic	0.011	0.13	1.146	67,566	9,833	77,400	35,563	8,891	44,454	66%
5	Kriging	0.06	0.18	1.573	47,127	27,019	74,146	45,463	5,609	51,071	100%*
6	Stochastic	0.06	0.18	1.573	93,554	53,637	147,191	47,880	14,084	61,963	66%

*The model predicted a dissolved mass recovery of 108% due to limited recovery of the sorbed mass.

Kd = distribution coefficient

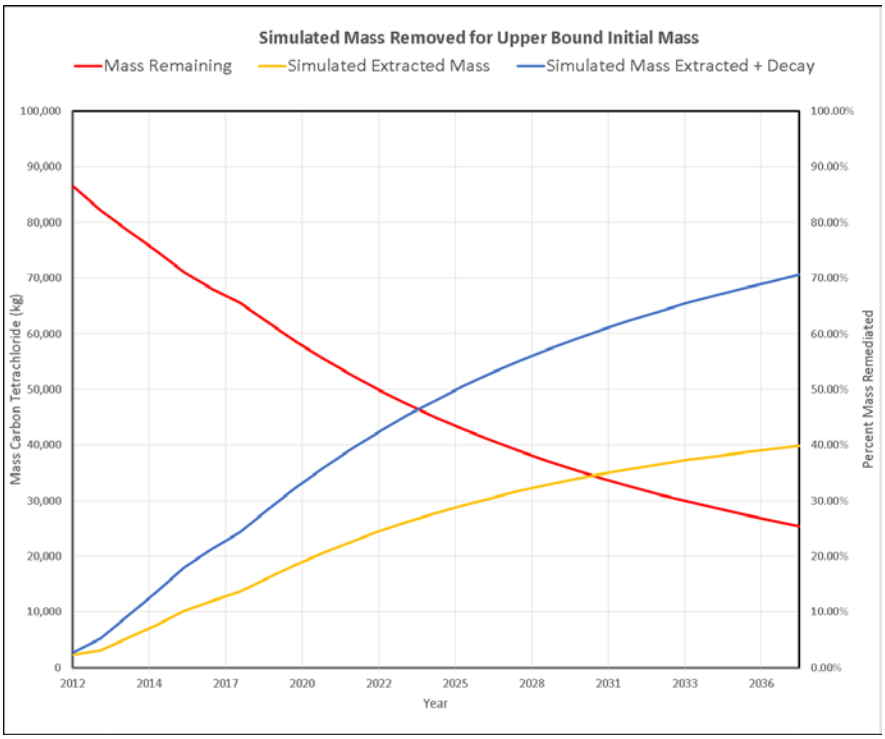


Figure 4-47. Simulated Carbon Tetrachloride Mass Removal for Upper Bound Initial Mass Condition

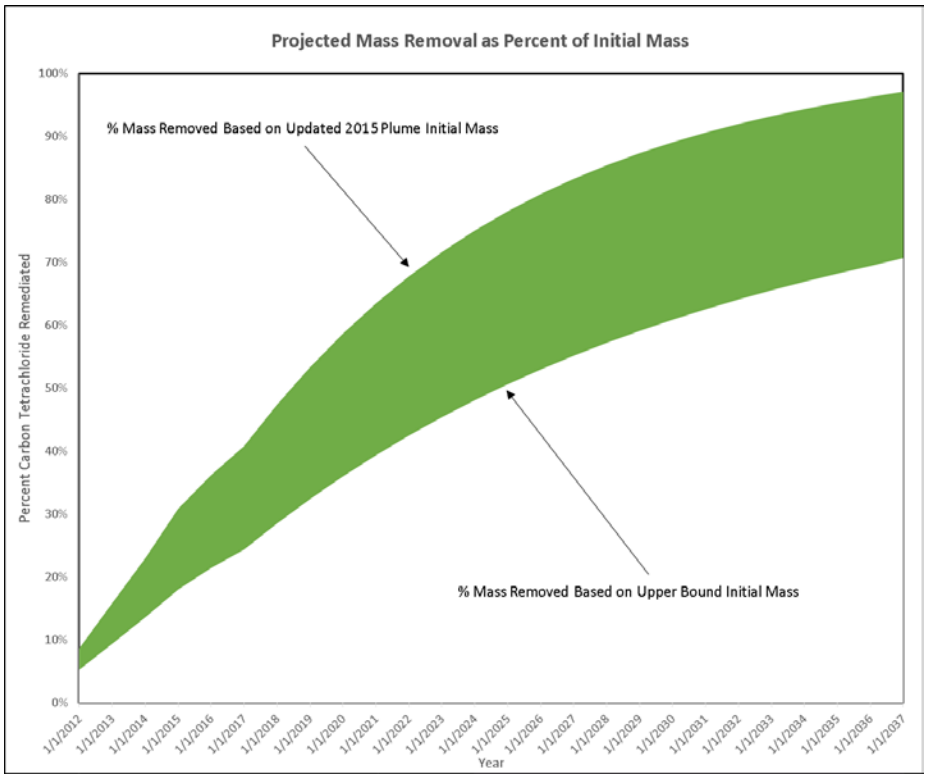


Figure 4-48. Percent Carbon Tetrachloride Mass Removal Range

4.7 Remedial Action Objectives

The RAOs identified in the final 200-ZP-1 ROD (EPA et al., 2008) are site-specific goals that define the extent of cleanup necessary to achieve the specific level of remediation at the site. Measurable progress was made during the reporting period to meet specific RAOs with the following results:

- **RAO #1**: Return the 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving the cleanup levels (Table 4-1). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated period to achieve cleanup levels is within 150 years.

  Results: The interim and final 200 West P&T systems have made progress toward this objective. The shallow portion of the aquifer (upper 15 m [50 ft]) with the carbon tetrachloride plume was captured by the interim 200-ZP-1 P&T system until operations were terminated in May 2012. Since remediation efforts began in 1996, the area with carbon tetrachloride concentrations greater than 2,000 µg/L decreased in size from 0.53 to 0.27 km^2 (0.2 to 0.1 mi^2). From 1996 to May 2012, the interim system removed 13,718 kg of carbon tetrachloride from groundwater. In 4.5 years of operation since July 2012, the 200 West P&T successfully treated groundwater to cleanup levels for all COCs, removing 10,985 kg of carbon tetrachloride; 1,174,990 kg of nitrate as nitrate (265,311 kg of nitrate as nitrogen); 320 kg of chromium; 45 kg of TCE; and 432 g of technetium-99.

- **RAO #2**: Apply ICs to prevent the use of groundwater until the cleanup levels (Table 4-1) have been achieved. Within the entire OU groundwater plumes, ICs must be maintained and enforced until the cleanup levels are achieved, which is estimated to be within 150 years.

  Results: The Hanford Sitewide ICs plan (DOE/RL-2001-41) has been implemented to prevent the use of groundwater until cleanup levels have been achieved, which is estimated to be within 150 years.

- **RAO #3**: Protect the Columbia River and its ecological resources from degradation and unacceptable impact caused by contaminants originating from the 200-ZP-1 OU. This final objective is applicable to the entire 200-ZP-1 OU groundwater plume. Protection of the Columbia River from impacts caused by the 200-ZP-1 OU contaminants must continue until cleanup levels are achieved, which is estimated to be within 150 years.

  Results: The 200 West P&T and flow-path control components of the remedy are concurrently implemented to protect the Columbia River and its ecological resources from degradation and unacceptable impacts caused by contaminants from the 200-ZP-1 OU. After extraction and treatment (to reduce constituent levels to cleanup levels or below) at the 200 West P&T, the water is injected into the aquifer to the west to direct groundwater flow eastward toward the extraction wells. Treated groundwater is also injected to the northeast and east of the groundwater contamination to slow the natural eastward flow of most of the groundwater and, as a result, keep the contaminants within the hydraulic capture zone of the extraction wells. Slowing groundwater flow eastward also increases the time available for natural attenuation processes to reduce the concentrations of contaminations not captured by the extraction wells.

4.8 Quality Assurance/Quality Control

Discussions on QA and QC encompassing sampling and analysis of all applicable wells are provided in Appendix D of DOE/RL-2016-67. Appendix F of that document includes an overall view of the QA/QC issues that may affect interpretation of the groundwater data for the 200 West P&T OUs.

4.9 Conclusions

The following conclusions are made regarding the 200-ZP-1 OU and 200 West P&T:

- Data obtained from the 200 West P&T have at times demonstrated that it is capable of operating at its nominal design capacity of 9,092 L/min (2,000 gpm). During 2016 the average facility throughput from the 26 extraction wells pumping to the 200 West P&T is 6,044 L/min (1,597 gpm) with a maximum average pumping rate of 8,191 L/min (2,164 gpm). However, this is an 8% decrease from the 2015 throughput of 7,447 L/min (1,966 gpm). The decrease is mainly attributed to reduced throughput as a result of the leak in FBR A. The average 200-ZP-1 pumping rate for each extraction well for 2016 was 276 L/min (73 gpm), which is slightly below the range of the design pumping rate of 303 to 492 L/min (80 to 130 gpm). However, this average extraction rate does not reflect a reduction in the extraction well capacity but rather a reduction in the ability of the injection wells to replace the treated water into the aquifer (biofouling), thereby placing a limitation on the system extraction rate.

- Biofouling and plugging of the injection wells has a direct impact to the system extraction rate. Biofouling was first observed in 2013 whereupon CHPRC optimized chemical dosing to the biological treatment system to balance biological needs within the plant while minimizing the release of substances that might foul the injection wells (iron oxide, manganese oxides, micro-organisms, and extracellular material). Ongoing rehabilitation of injection wells continued to be performed to remove metal oxides and bio-films generated from the 200 West P&T bio-remediation component. In 2016, injection wells were taken offline and cleaned to remove clogging material and restore injection capacity. Recommendations to minimizing biofouling issues to improve injection well capacity are planned for implementation in 2017.

- Capture zones induced by pumping of the 200-ZP-1 extraction in injection wells cover most of the carbon tetrachloride plume at concentrations greater than 100 µg/L, as designed. Portions of the carbon tetrachloride plume at concentrations greater than 100 µg/L downgradient of the eastern line of extraction wells are not being captured. Modeling will be performed to help evaluate whether concentrations in portions of the plumes not being captured will be reduced to below cleanup levels by MNA.

- Contaminant monitoring indicates a decrease in contaminant concentration compared to baseline concentrations established in 2012 prior to startup of the 200 West P&T. There were also monitoring wells with higher concentrations than observed in 2012, attributed to plume movement induced by the P&T remedy. Several monitoring wells with higher concentrations than observed in 2012 are near extraction wells.

5 200-DV-1 Operable Unit Perched Water Removal Action

This chapter discusses the removal action activities performed for contaminated perched water within the 200-DV-1 OU during 2016. Perched water operations are included in this annual report because they are being conducted as a non-time-critical removal action (NTCRA) and the extracted water is treated at the 200 West P&T. Annual reports for perched water extraction in FY 2012 through FY 2015 are provided as separate documents (Table 5-1).

Table 5-1. Previous Annual Reports on Perched Water Extraction Operations

Fiscal Year	Duration	Report
2012	08/2011 - 09/2012	SGW-53604, Rev. 0, *Path Forward Recommendations Report for the Uranium Contamination in the B Area*
2013	10/2012 - 09/2013	SGW-53604, Rev. 1, *Path Forward Recommendations Report for the Uranium Contamination in the B Area*
2014	10/2013 - 09/2014	SGW-58147, *Annual Performance Report for the 200-DV-1 Operable Unit Perched Water Extraction, Fiscal Year 2014*
2015	10/2014 - 09/2015	SGW-59086, *Annual Performance Report for the 200-DV-1 Operable Unit Perched Water Extraction, Fiscal Year 2015*

Contaminated perched water is present in the deep vadose zone at the B Complex Area located in the Inner Area (Figure 5-1). The B Complex Area includes waste sites in the 200-DV-1 OU and the SST farms in WMA B-BX-BY (Figure 5-2). Perched water was discovered in this area in 1991 during drilling of RCRA wells to characterize groundwater contamination in the underlying unconfined aquifer in the 200-BP-5 OU. In 2008, significant perched water was encountered during the drilling of well 299-E33-344 as part of the CERCLA remedial investigation of the 200-BP-5 OU. The perched water contains high concentrations of uranium, technetium-99, and nitrate.

Perched water is a continuing source of contamination to groundwater in the underlying unconfined aquifer. Characterization and remediation of the contaminated perched water is being conducted as part of the 200-DV-1 OU, which was created in 2010 to support remedy selection for waste sites with deep vadose zone contamination. The perched water zone is estimated to extend from the east-central portion of the BX Tank Farm northeast to the 216-B-8 Crib and to include the northwest portion of the B Tank Farm (Figure 5-2). The top of the perched water zone is approximately 68.6 m (225 ft) bgs and extends to 4.6 m (15 ft) above the water table at its lowest point. The maximum thickness of the perched water zone is 4.6 m (15 ft).

Extraction of the contaminated perched water using well 299-E33-344 began in August 2011 to collect information on the perched zone and to reduce migration of contamination to the unconfined aquifer. Two additional 200-DV-1 OU perched water extraction wells were drilled in 2014 (wells 299-E33-350 and 299-E33-351). Extraction of perched water using all three wells began in 2016 as a NTCRA (DOE/RL-2014-34, *Action Memorandum for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*). The removal action work plan (DOE/RL-2014-37, *Removal Action Work Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*) and associated sampling and analysis plan (SAP; DOE/RL-2014-51, *Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*) for the NTCRA were issued in November 2015.

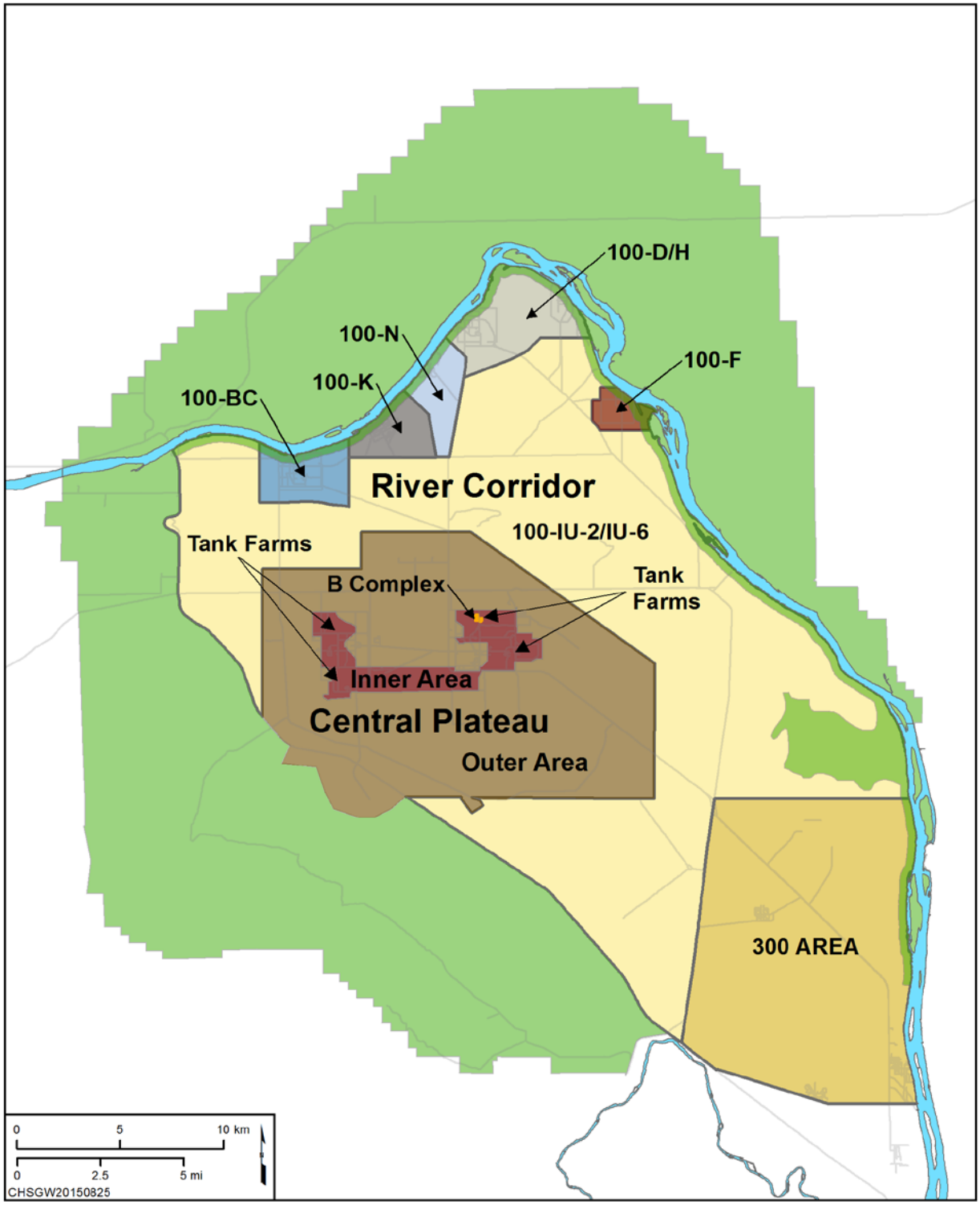


Figure 5-1. Location of the B Complex Area on the Hanford Site

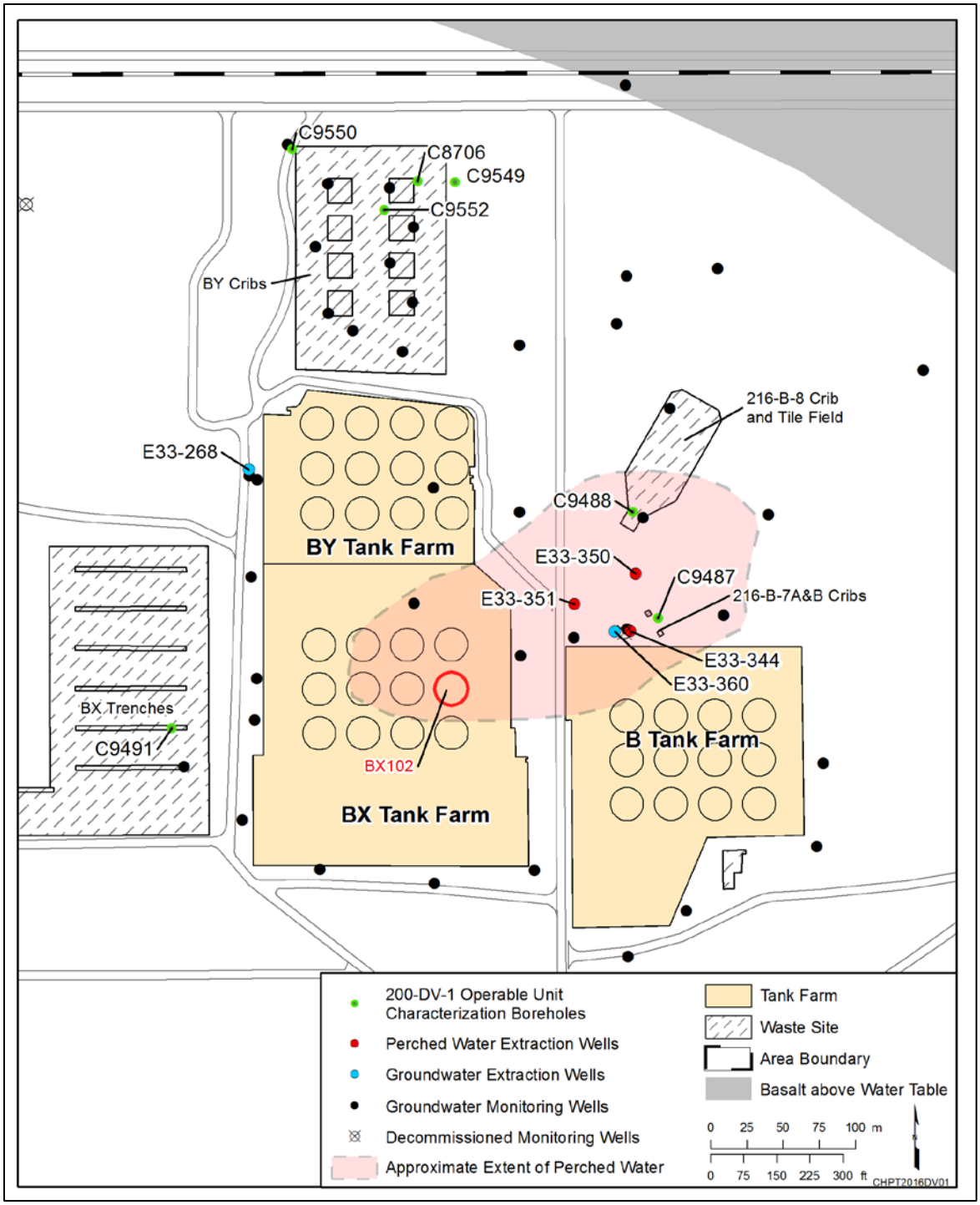


Figure 5-2. Location of Waste Sites, Tank Farms, Wells, and Estimated Extent of Perched Water in the B Complex Area

The removal action objectives for perched water removal are defined in the action memorandum (Section 5.1 of DOE/RL-2014-34) as follows:

- Apply ICs to protect human receptors from exposure to contaminants that exceed MCLs in the underlying aquifer.
- Control sources of groundwater contamination.
- Remove contaminant mass from perched water and support final remedial options for both the 200-DV-1 and 200-BP-5 OUs.

During configuration of the extraction system to pump from all three extraction wells, pressure and flow sensors suitable for conducting hydraulic testing were installed on each well. Hydraulic testing was conducted during startup of the three-well extraction system. The testing program was designed by Pacific Northwest National Laboratory (PNNL) and implemented by CHPRC. The hydraulic testing began in February 2016 and was completed in September 2016. Aquifer tests were performed in all three perched water extraction wells to investigate water elevation, inter-well hydrologic properties, areal extent, hydrologic boundaries, and dewatering performance for the perched aquifer. Testing results were analyzed by PNNL and are included as Appendix A of this report.

Perched water samples were obtained from all three extraction wells during hydraulic testing. The samples were analyzed for all of the constituents identified in the SAP (Table 3-1 of DOE/RL-2014-51). The results for analyses of deuterium (^{2}H) and 18-oxygen (^{18}O) content are provided in PNNL-26341, *Letter Report: Stable Hydrogen and Oxygen Isotope Analysis of B-Complex Perched Water Samples*.

From February through September 2016, extracted perched water was pumped to an aboveground collection container and transferred by truck from the container to the 200 West P&T. During October through December 2016, the extraction system was not operated while new equipment to transfer extracted perched water to the 200 West P&T was being installed and tested. Pumps and piping were added to transfer extracted perched water from the existing collection container to a nearby, larger, aboveground container used to collect groundwater extracted from the underlying 200-BP-5 OU. The 200-BP-5 OU container was connected to the 200-BP-5 OU cross-site pipeline to allow 200-DV-1 OU extracted perched water and 200-BP-5 OU extracted groundwater to be transferred through this pipeline from the 200-BP-5 OU collection container to the 200 West P&T. It is expected that the cross-site transfer pipeline will be used in 2017 to convey extracted perched water to the 200 West P&T.

In 2016, the perched water extraction wells removed 224,434 L (59,289 gal) of perched water containing 11.2 kg of uranium, 0.36 g of technetium-99, and 195.0 kg of nitrate. Since perched water extraction began in 2011, a total of 1,364,306 L (360,444 gal) of perched water containing 79.7 kg (176 lb) of uranium, 2.5 g (5.4×10^{-3} lb) of technetium-99, and 778.0 kg (1,715 lb) of nitrate has been removed from the perched zone.

Two boreholes were drilled into the perched aquifer during 2016 as part of characterization of the 200-DV-1 OU waste sites. Sediment and perched water samples were collected from borehole C9487, drilled near the 216-B-7A&B Cribs, and borehole C9488, drilled at the 216-B-8 Crib (Figure 5-2). The samples were analyzed for contaminants and soil properties to help understand the perched water aquifer boundaries and contaminant fate and transport in the perched water zone. The analytical results will be provided in a separate report.

The conceptual site model for the perched water zone will be updated and presented in a separate report.

5.1 Removal System Operation

During 2016, the perched water extraction system operated from February through September 2016. During October through December 2016, the system was not operated while the transfer pipeline system to the 200 West P&T was being installed and tested.

5.1.1 Overview of Removal System

In 2016, perched water was pumped from extraction wells 299-E33-344, 299-E33-350, and 299-E33-351. A dedicated submersible pump was installed in each well with an automatic on-off pump control regulated by a water level sensor (transducer; Figure 5-3). When the perched water level in the well reaches the high-level set point, the pump turns on and the water is pumped into an aboveground, 11,000 L (3,000 gal) high-density polyethylene double-wall collection container located near the wellhead. Once pumping lowers the water level to the low-level set point, the pump shuts off to allow the well to recover.

Well 299-E33-344 has a 10.2 cm (4 in.) diameter casing with a 5.9 m (19.2 ft) long screen. Wells 299-E33-350 and 299-E33-351 have 15.2 cm (6 in.) diameter casings with 3.0 m (10 ft) long screens.

The collection container was emptied every other day by a purge water truck that transferred approximately 7,570 L (2,000 gal) of extracted perched water to an offload system inlet tank at the 200 West P&T. The perched water was then pumped into the uranium inlet tank where it was mixed with 200-BP-5 OU and 200-UP-1 OU extracted groundwater and with ERDF leachate. The mixed water was sent through the uranium and technetium-99 treatment systems and finally to the central treatment plant where the remaining contaminants were removed. In 2017, it is expected that the extracted perched water will be transferred from the aboveground collection container to a larger 200-BP-5 OU aboveground collection container in the same vicinity. The perched water and the 200-BP-5 OU extracted groundwater will be conveyed through a cross-site transfer pipeline from the 200-BP-5 OU collection container to the 200 West P&T.

5.1.2 Startup Hydraulic Testing

Hydraulic testing was conducted in 2016 during startup of pumping from the three perched water extraction wells. The hydraulic tests were designed and analyzed by PNNL. Test results are summarized in this section and details are provided in Appendix A of this report. The test schedule is shown in Table 5-2.

Test 1, Baseline Monitoring, was conducted to establish barometric pressure response functions for the perched water extraction wells. The barometric response functions enabled removing barometric pressure effects in the water level data for Tests 2 and 3 and provided insight into the vadose zone overlying the perched water aquifer. During Test 1, each well was individually pumped for 1 hour, followed by a 30-day recovery period (Table 5-2).

Test 2, Single-Well Pumping Test, was conducted to determine aquifer properties adjacent to each well. During Test 2, each well was individually pumped for 7 days, followed by a 14-day recovery period (Table 5-2).

Test 3, Multi-Well Pumping Test, was conducted to assess the perched water aquifer extent. During Test 3, all three wells were planned to be simultaneously pumped for 60 days, followed by a 60-day recovery period. The Test 3 pumping duration was longer than in Test 2 to allow the pumping stress to the aquifer to propagate a long distance from the pumping wells. Test 3 pumping began on May 17, 2016. On May 26, the pump in well 299-E33-351 failed, and the well was used only for monitoring for the duration of the test (Table 5-2).

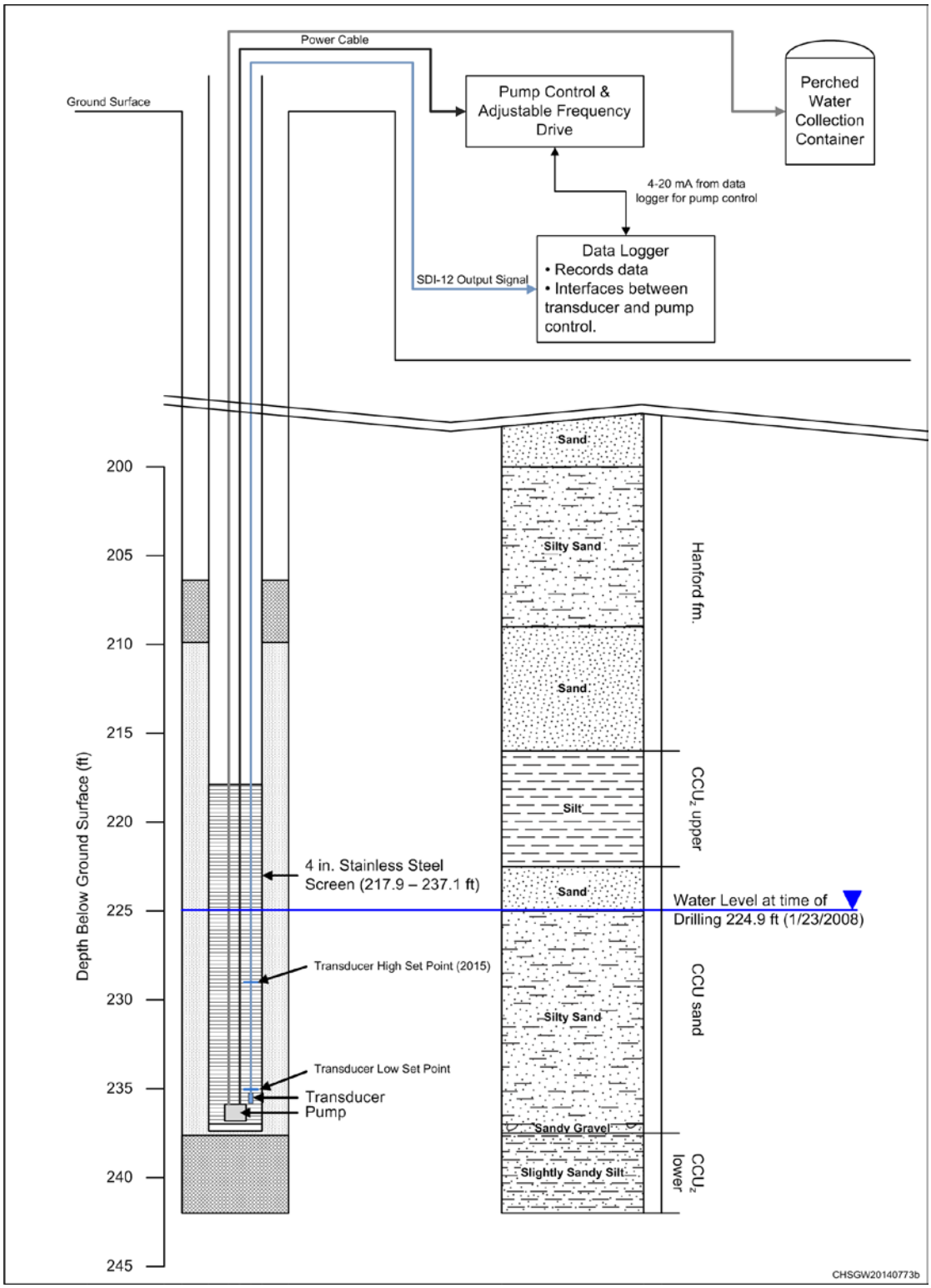


Figure 5-3. Configuration of Perched Water Extraction Well 299-E33-344

Table 5-2. Hydraulic Testing Schedule

Dates (2016)	Activity
02/18–02/18	Conducted Test 1 pumping cycles for 1 hr sequentially at each well.
02/20–03/21	Collected water level and barometric data at all three wells during Test 1 recovery.
03/21–03/28	Conducted Test 2 pumping cycles at well 299-E33-344 with monitoring at wells 299-E33-350 and 299-E33-351; cyclical pumping duration abbreviated due to operational pump and well pressure setting constraints.
03/28–04/11	Collected water level and barometric data at all three wells during Test 2 recovery.
04/11–04/14	Conducted Test 2 pumping cycles at well 299-E33-350 with monitoring at wells 299-E33-344 and 299-E33-351.
04/14–04/25	Collected water level and barometric data at all three wells during Test 2 recovery.
04/25–05/02	Conducted Test 2 pumping cycles at well 299-E33-351 with monitoring at wells 299-E33-344 and 299-E33-350.
05/02–05/17	Collected water level and barometric data at all three wells during Test 2 recovery.
05/17–07/18	Conducted Test 3 pumping cycles simultaneously at all three wells; the pump failed in well 299-E33-351 on 05/26, after which the well was used for monitoring.
07/18–09/16	Collected water level and barometric data at all three wells during Test 3 recovery.

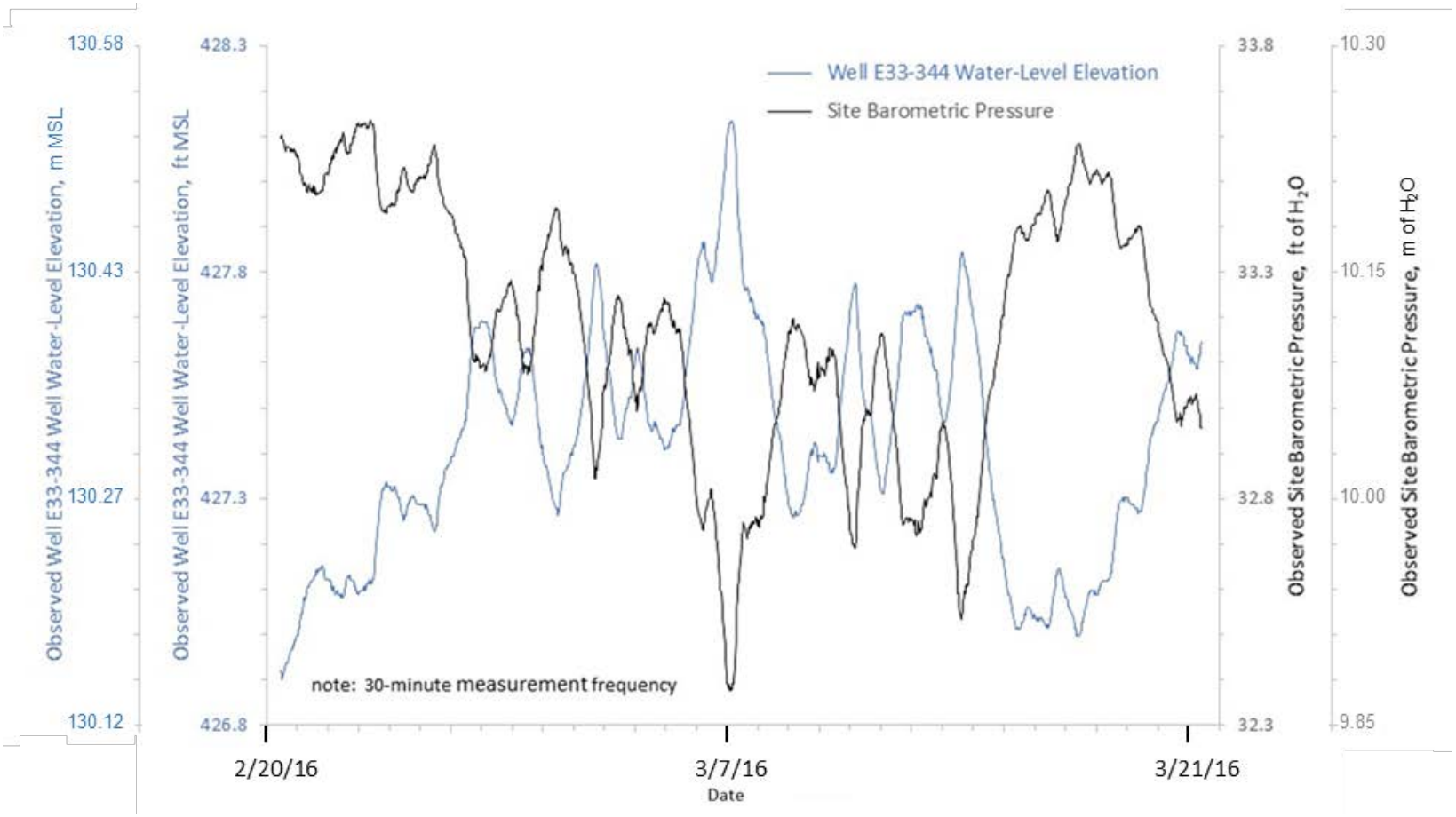
During Test 1, the volumes of perched water pumped from wells 299-E33-344, 299-E33-350, and 299-E33-351 in 1 hour were 67.46 L (17.82 gal), 412.76 L (109.04 gal), and 231.97 L (61.28 gal), respectively.

During Test 1, the barometric and water level data fluctuated inversely over a range of about 0.37 m (1.2 ft; Figure 5-4). Each well showed a similar response. Barometric response functions generated using Test 1 data accounted for about 80% of the water level barometric dependence.

The volumes of perched water pumped from wells 299-E33-344, 299-E33-350, and 299-E33-351 during Test 2 and the pumping rates are provided in Table 5-3. The pumping rates were adjusted to meet aboveground water-handling constraints and do not necessarily reflect maximum pumping rates.

The Test 2 data at each well were evaluated using a single-well (pumped-well) analysis to estimate hydraulic properties (Table 5-4). The hydraulic properties were estimated based on only the pumping well data (i.e., not on the observation well data) using the barometric response functions from Test 1.

During Test 3, the volumes of perched water pumped from wells 299-E33-344, 299-E33-350, and 299-E33-351 were 56,790 L (15,004 gal), 126,726 L (33,481 gal), and 24,455 L (6,461 gal), respectively. The pumping rates were adjusted to meet aboveground water-handling constraints and do not necessarily reflect maximum pumping rates.



Source: Figure 1 in Appendix A.

Figure 5-4. Baseline Water Level and Barometric Pressure Data for Well 299-E33-344 during Hydraulic Test 1

Table 5-3. Volumes Extracted and Pumping Rates during Hydraulic Test 2

Well	Number of Uninterrupted Pumping Cycles	Number of Pumping Days	Volume Extracted L (gal)	Average Flow Rate L/m (gpm)	Average Cycle Time On	Average Cycle Time Off	Average In-Cycle Pumping Rate L/m (gpm)
299-E33-344	299	7	6188 (1635)	0.61 (0.162)	1.3	32.6	16.3 (4.3)
299-E33-350	113	3.5	5768 (1524)	1.14 (0.302)	5.7	39.3	9.1 (2.4)
299-E33-351	496	7	9762 (2579)	0.97 (0.256)	2.5	17.8	9.8 (2.6)

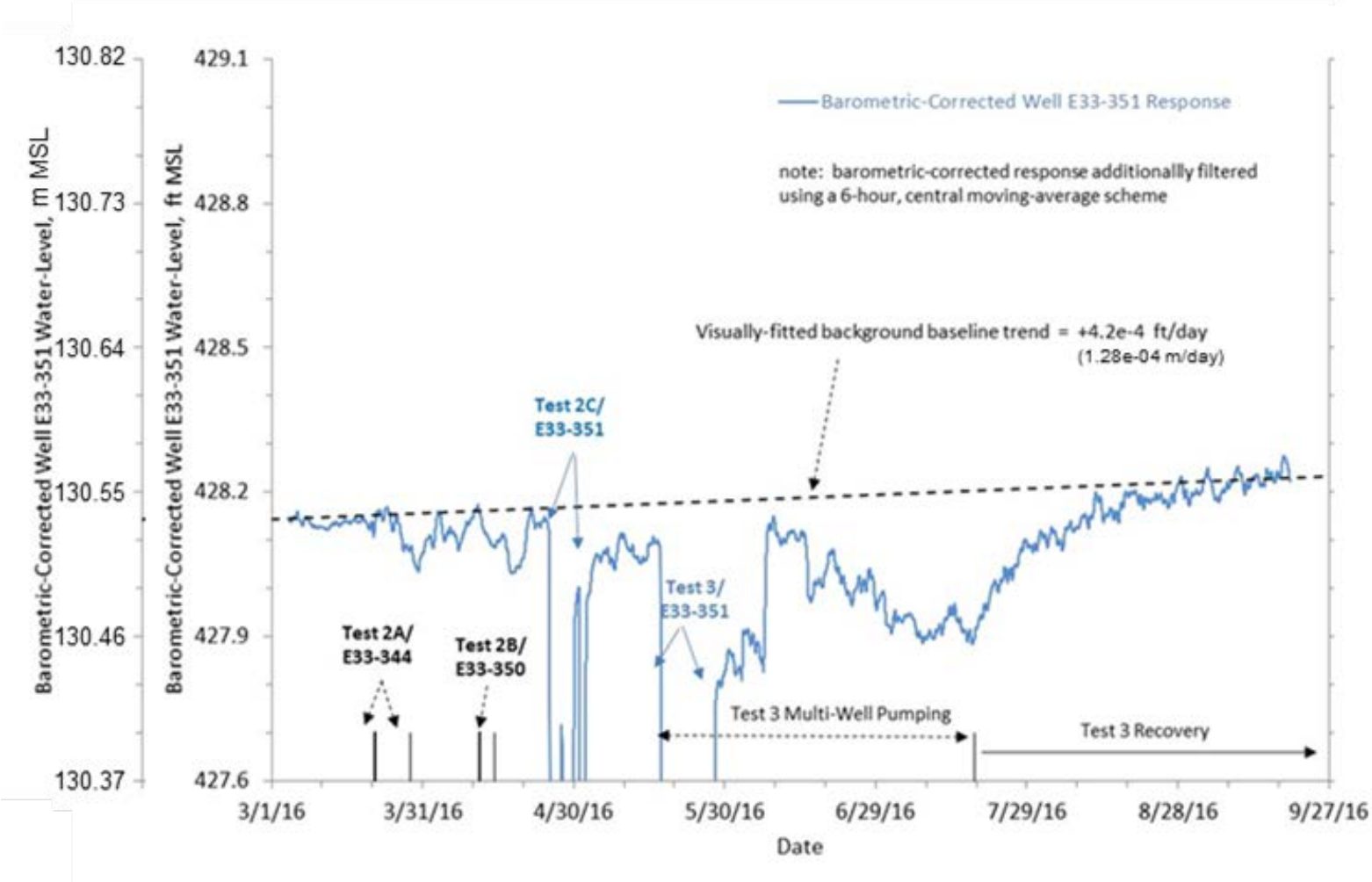
Table 5-4. Estimated Perched Water Aquifer Hydraulic Properties

Well	T m^2/day (ft^2/day)	K_h m/day (ft/day)	S	S_y	β_w	K_v/K_h
299-E33-344	0.51 (5.45)	0.13 (0.44)	1.33E-03	0.151	5.5E-05	0.03
299-E33-350	4.01 (43.1)	1.05 (3.45)	4.5E-03	0.273	3.2E-05	0.02
299-E33-351	3.50 (37.6)	0.91 (3.00)	9.0E-04	0.220	1.5E-05	0.01

b = perched water aquifer saturated thickness, assumed to be 3.81 m (12.5 ft) for all analyses
K_h = horizontal hydraulic conductivity
K_v = vertical hydraulic conductivity
K_v/K_h = vertical anisotropy
r_w = well radius
S = storativity
S_y = specific yield
T = transmissivity: $T = K_h b$
β_w = beta: $\beta_w = (r_w/b)^2 (K_v/K_h)$

While the Test 3 pumping rate was lower than initially planned due to the logistics of aboveground treatment and the failure of the pump in well 299-E33-351, the pumped volume should have been sufficient to cause a measurable dewatering response if the perched aquifer areal extent were equal to or less than about 33,500 m^2 (361,000 ft^2), and there were no continuing net influx of water to the perched aquifer. Because the calculated dewatering values were greater than the detection limit for the barometric-corrected well pressure response, it was expected that a measurable dewatering would have been observed for Test 3 (Appendix A).

Barometric-corrected water level data at well 299-E33-351 (Figure 5-5), which acted as an observation well for Test 3 because its pump failed early in the test, showed rapid and complete recovery of the water level to pre-test conditions. The pumping and recovery data for well 299-E33-351 do not show any characteristics of a hydrologic boundary (i.e., the edge of the perched water aquifer). The data also do not indicate any dewatering response. These results are interpreted as meaning either that the perched water aquifer is larger in extent than currently conceptualized or that the effects of pumping (e.g., dewatering, hydraulic recovery) are being affected by the recharge (influx) and discharge (outflux) water balance for the perched water aquifer (Appendix A).



Source: Figure 7 in Appendix A.

Figure 5-5. Water-Level Data for Observation Well 299-E33-351 during Hydraulic Test 3

5.1.3 Contaminant Monitoring

During 2016, all contaminant monitoring of perched water was conducted during the startup hydraulic testing. Routine monitoring of perched water in accordance with the SAP (DOE/RL-2014-51) is anticipated to begin in 2017.

The perched water extraction wells were sampled during Hydraulic Tests 2 and 3. During Test 2, samples were collected from each well on Day 1 and Day 4 of the 7-day pumping test. The first sample was collected within the first 24 hours of pumping to provide data to the 200 West P&T. The second sample was collected on the fourth day of pumping to be more representative of a sample collected after a typical purge volume had been pumped.

During Test 3, samples were planned to be collected during the 60-day pumping test on the following schedule: Day 1; after 1 week; after 2 weeks; after 4 weeks; after 6 weeks; and after 8 weeks. The sampling schedule during Test 3 was selected to sample perched water pumped from increasing radial distances from each well. At the end of the previous extraction operations, well 299-E33-344 was producing approximately 6000 L/wk (1500 gal/wk; SGW-59086, *Annual Performance Report for the 200-DV-1 Operable Unit Perched Water Extraction, Fiscal Year 2015*). Based on this recovery rate and a 2 m thick saturated perched zone, sampling after weeks 1, 2, 4, 6, and 8 represented sampling at increasing radial distances of 2, 3, 4, 5, and 6 m from each well. Wells 299-E33-344 and 299-E33-350 were sampled according to this schedule. Well 299-E33-351 was sampled on the first day and after 1 week of pumping before the extraction pump failed.

Tables 5-5, 5-6, and 5-7 provide analytical results for uranium, technetium-99, and nitrate for samples collected from the three perched water extraction wells.

Table 5-5. Well 299-E33-344 Perched Water Analytical Results

Sampling Date	Nitrate (mg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
01/08/2008	326	5,990	—
07/15/2008	436	4,400	897
09/19/2008	522	4,130	788
11/18/2008	483	4,800	1,820
05/22/2009	—	5,400	1,460
06/26/2009	474	—	—
08/04/2009	481 *	5,850 *	5,120 *
11/12/2009	425 *	6,100 *	2,945 *
05/24/2010	469	5,900	1,660
12/19/2010	580	4,860[a]	409
09/07/2011	401	5,640	4,500
10/04/2011	604	37,800	63,600
12/05/2011	810	45,100	71,500

Table 5-5. Well 299-E33-344 Perched Water Analytical Results

Sampling Date	Nitrate (mg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
04/23/2012	456	22,100	51,500
08/02/2012	522	12,200	26,600
02/05/2013	637	51,000	37,300
08/13/2013	474	33,000	60,800
10/22/2013	—	—	104,000 *
04/22/2014	492 *	45,000 *	57,450 *
06/24/2014	316	15,700	28,800
07/30/2014	360	17,200	29,700
08/20/2014	580	42,500	77,500
09/25/2014	611	53,300	99,300
10/30/2014	361	20,400	40,600
11/19/2014	332	16,400	30,900
12/30/2014	368	17,200	37,800
02/26/2015	351	20,300	111,000
05/20/2015	540	35,200	76,100
08/11/2015	620	40,900	83,900
03/21/2016	443	23,300	42,000
03/24/2016	398	8,460	27,000
05/17/2016	443 *	23,450 *	44,250 *
05/24/2016	336	11,600	23,000
05/31/2016	443	24,600	45,000
06/14/2016	443	22,200	47,000
06/28/2016	620	41,100	77,000
07/13/2016	531	33,300	67,000

* Duplicate results are averaged.

Table 5-6. Well 299-E33-350 Perched Water Analytical Results

Sampling Date	Nitrate (mg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
02/20/2014 [a]	460	4,100	16,400
02/24/2014 [a]	1,845 [b]	9,400 [b]	106,500 [b]
04/11/2016	1,110	50,100	150,000
04/14/2016	797	24,600	80,000
05/17/2016	841	31,400	96,000 [b]
05/24/2016	708 [b]	28,000 [b]	74,500 [b]
05/31/2016	974	38,800	100,000
06/14/2016	974	47,900	79,000
06/28/2016	797	32,000	75,000
07/13/2016	1,020	41,200	100,000

a. Sampled during drilling.
b. Duplicate results are averaged.

Table 5-7. Well 299-E33-351 Perched Water Analytical Results

Sample Date	Nitrate (mg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
01/29/2014 [a]	1,000 [b]	7,100 [b]	27,700 [b]
01/30/2014 [a]	5,930	30,000	49,800
04/25/2016	1,280	16,900	46,000
04/28/2016	1,730 [b]	26,250 [b]	41,500 [b]
05/17/2016	1,640	24,500	39,000
05/24/2016	1,550	24,400	39,000

a. Sampled during drilling.
b. Duplicate results are averaged.

The concentrations of uranium, and technetium-99 in well 299-E33-344 still remain higher than before pumping began in 2011 and have continued to fluctuate over time (Figure 5-6). Figures 5-7 through 5-9 show the 2016 concentrations of uranium, technetium-99, and nitrate in samples collected from the three perched water extraction wells. Concentrations of uranium and technetium-99 were higher in perched water from well 299-E33-350. Nitrate concentrations were highest in perched water from well 299-E33-351. In well 299-E33-344, the concentrations of both uranium and technetium-99 increased from March to July. In well 299-E33-350, the concentrations of uranium and technetium-99 varied from April to July. In well 299- E33-351, the concentrations or uranium and technetium-99 remained stable from April to May (last sample).

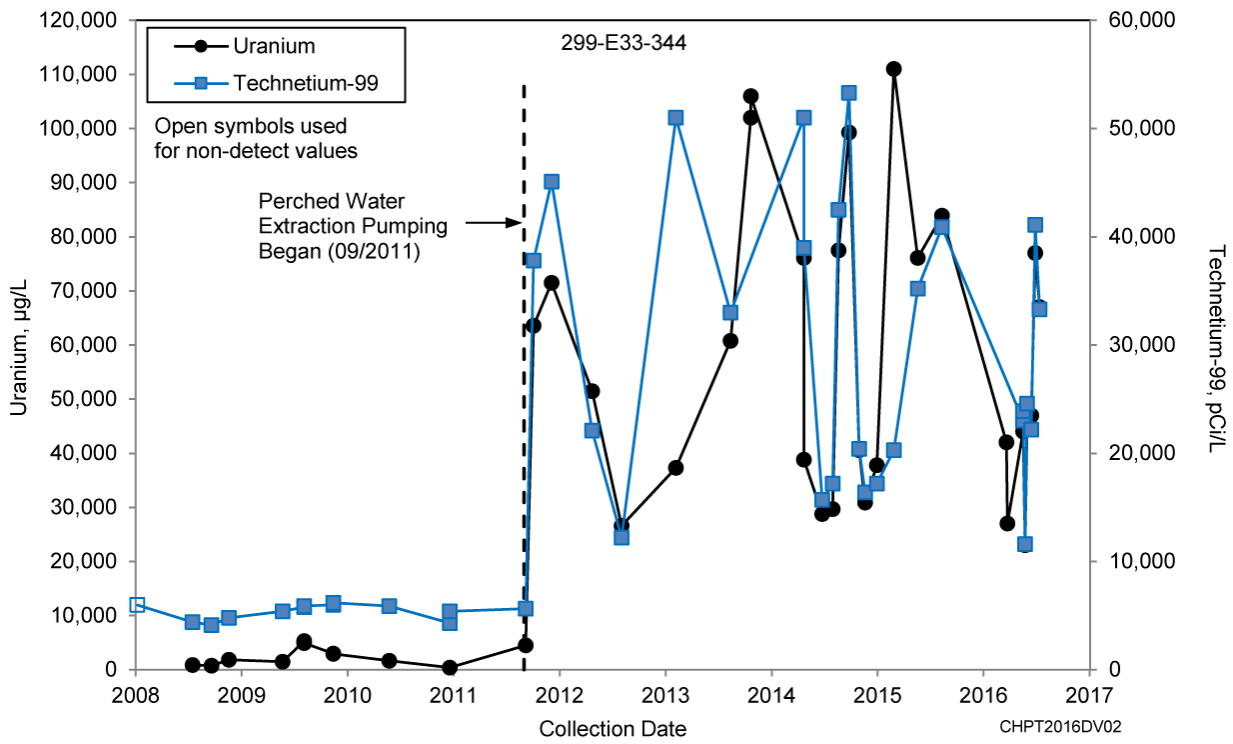


Figure 5-6. Increase in Uranium and Technetium-99 Concentrations in Perched Water Extraction Well 299-E33-344 after Pumping Began

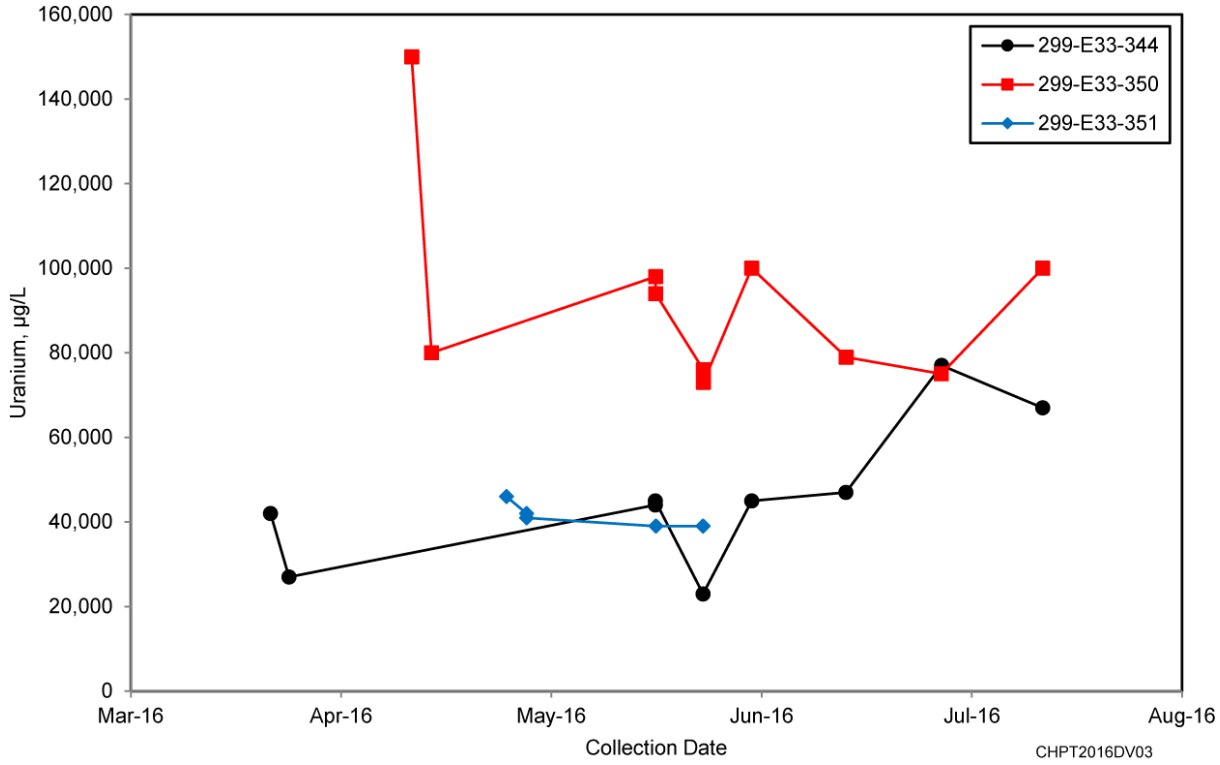


Figure 5-7. Uranium Trends in Wells 299-E33-344, 299-E33-350, and 299-E33-351, 2016

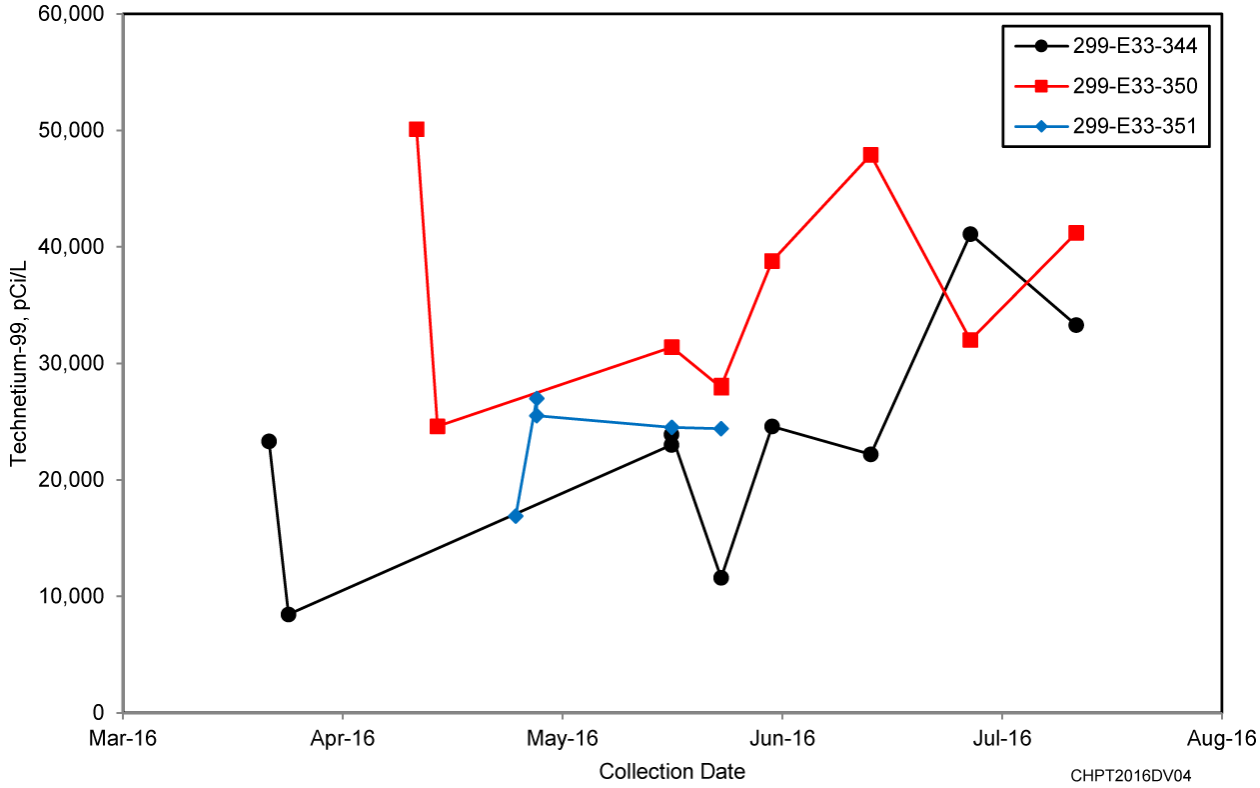


Figure 5-8. Technetium-99 Trends in Wells 299-E33-344, 299-E33-350, and 299-E33-351, 2016

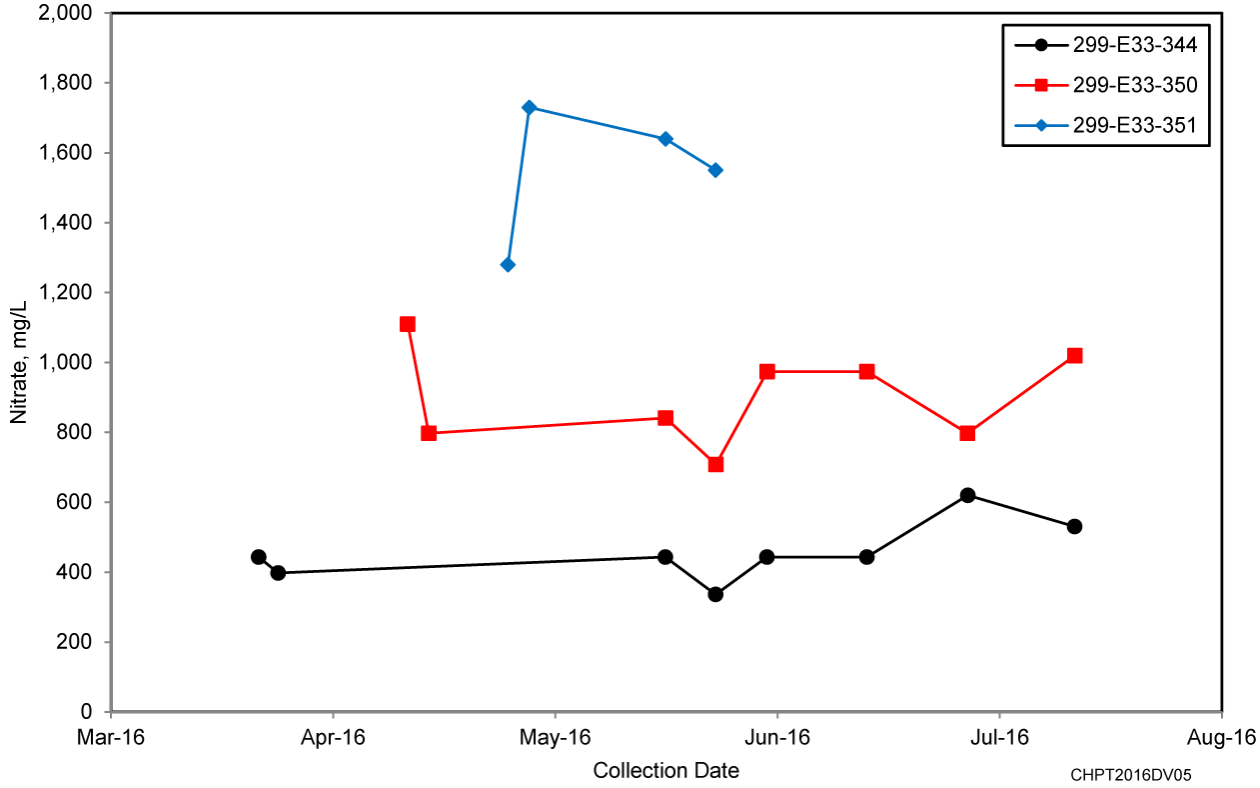


Figure 5-9. Nitrate Trends in Wells 299-E33-344, 299-E33-350, and 299-E33-351, 2016

The samples from the perched water wells were analyzed for the COCs, non-COCs, and other analytes and field parameters of interest specified in the SAP (Table 3-1 of DOE/RL-2014-51). All of the required constituents for all sampling frequencies were analyzed in all of the 2016 samples. Table 5-8 provides the maximum concentrations detected during 2016 for the analytes required by the SAP (DOE/RL-2014-51).

The following 10 samples were selected for analysis of hydrogen and oxygen isotopes: the Day 1 and Day 4 samples during Hydraulic Test 2 at all three wells, and the Week 4 and Week 6 samples during Hydraulic Test 3 at wells 299-E33-344 and 299-E33-350. The samples were submitted to PNNL for determination of deuterium (^{2}H) and 18-oxygen (^{18}O) content. The Day 1 sample from well 299-E33-344 was not analyzed because the elevated radioactivity would have contaminated the analytical instrument. The results are provided in PNNL-26341.

Table 5-8. Maximum Contaminant Concentrations Detected during 2016 Perched Water Operations

Constituent	Units	Well 299-E33-344	Well 299-E33-350	Well 299-E33-351
		Maximum	Maximum	Maximum
Contaminants of Concern				
Uranium	µg/L	77,000 D	150,000 D	46,000
Technetium-99	pCi/L	41,100	50,100	27,000
Nitrate as N	mg/L	620	1,100 D	1,730 D
Total chromium	µg/L	210	100 D	92
Hexavalent chromium	µg/L	210	100	70
Tritium	pCi/L	19,200	28,000	8,210
Non-Contaminants of Concern				
Carbon-14	pCi/L	1,340	1,840	799
Iodine-129	pCi/L	3.69	6.61	8.27
Arsenic	µg/L	21 BD	14 BD	2.8
Calcium	mg/L	180	280	330
Iron	µg/L	1,600	830	190
Sodium	mg/L	330 D	370	460 D
Chloride	mg/L	77 D	100 D	93 D
Fluoride	mg/L	19 D	3.2 D	0.44 BD
Nitrite as N	µg/L	493 D	174 BD	427 BD
Sulfate	mg/L	470 D	680 D	680 D

Table 5-8. Maximum Contaminant Concentrations Detected during 2016 Perched Water Operations

Constituent	Units	Well 299-E33-344	Well 299-E33-350	Well 299-E33-351
		Maximum	Maximum	Maximum
Other Analytes Sampled at Startup				
Magnesium	mg/L	69	110	93
Potassium	mg/L	17	26	31
Bicarbonate alkalinity	mg/L	330	408	250
Carbonate alkalinity	µg/L	540 U	540 U	540 U
Total inorganic carbon	mg/L	62.6 D	68.5 D	48 D
Total organic carbon	mg/L	24.1 D	15.3	11.7
Total dissolved solids	mg/L	2,080	3,120 D	3,740 D
Field Parameters and Other Analytes of Interest				
Cyanide *	µg/L	4 B	13.1 C	8.9 BC
Dissolved oxygen	mg/L	6.76	5.89	7.85
Oxidation reduction potential	RmV	406.3	405.6	393.2
pH	unitless	7.92	7.87	7.64
Specific conductivity	µS/cm	2,480	3,709	4,706
Temperature	°C	22.4	24.4	19.5
Turbidity	NTU	4.05	11.4	1.72

* Not required by DOE/RL-2014-51, *Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*.

B = Estimated

C = The analyte was detected in both the sample and the associated QC blank, and the sample concentration was ≤5× the blank concentration.

D = Analyte was identified in an analysis at a secondary dilution factor (i.e., dilution factor different than 1.0).

U = Undetected

5.1.4 Contaminant Mass Removed

In 2016, the perched water extraction wells removed 224,434 L (59,289 gal) of perched water containing 11.2 kg of uranium, 0.36 g of technetium-99, and 195.0 kg of nitrate (Table 5-9). The 2011 through 2015 volumes and masses removed were from pumping only one extraction well, 299-E33-344.

Table 5-9. Perched Water Extracted and Contaminants Removed

Fiscal Year	Duration	Perched Water Extracted L (gal)	Uranium Removed kg (lb)	Technetium-99 Removed g (lb)	Nitrate Removed kg (lb)
2012	08/2011 - 09/2012	246,657 (65,167)	12.0 (26.5)	0.37 (8.1×10^{-4})	131.0 (288.9)
2013	10/2012 - 09/2013	349,367 (92,303)	13.1 (28.9)	0.74 (1.6×10^{-3})	202.6 (446.7)
2014	10/2013 - 09/2014	286,222 (75,620)	24.1 (53.2)	0.59 (1.3×10^{-3})	137.2 (302.4)
2015	10/2014 - 09/2015	257,626 (68,065)	19.3 (42.4)	0.41 (9.0×10^{-4})	112.2 (247.4)
2016	10/2015 - 12/2016	224,434 (59,289)	11.2 (24.7)	0.36 (7.8×10^{-4})	195.0 (430.0)
Total	08/2011 - 12/2016	1,364,306 (360,444)	79.7 (175.7)	2.5 (5.4×10^{-3})	778.0 (1,715.4)

5.2 Removal Action Objectives Progress

Measurable progress was made during 2016 to meet specific removal action objectives for perched water removal with the following results:

- Apply ICs to protect human receptors from exposure to contaminants that exceed MCLs in the underlying aquifer.

  Results: The Hanford Sitewide IC plan (DOE/RL-2001-41) has been implemented to prevent the use of groundwater until cleanup levels have been achieved.

- Control sources of groundwater contamination.

  Results: Extraction of perched water controls sources of groundwater contamination and removes contaminant mass from the perched water by pumping the contaminated water from the perched layer and treating it at the 200 West P&T to below MCLs in order to meet injection criteria.

- Remove contaminant mass from perched water and support final remedial options for both the 200-DV-1 and 200-BP-5 OUs.

  Results: During 2016, extraction of perched water using three extraction wells removed 224,434 L (59,289 gal) of perched water containing 11.2 kg (24.7 lb) of uranium, 0.36 g (0.01 oz) of technetium-99, and 195.0 kg (430 lb) of nitrate. Since 2011, perched water extraction has removed 1,364,306 L (360,444 gal) of water containing 79.7 kg (176 lb) of uranium, 2.5 g (5.4×10^{-3} lb) of technetium-99, and 778.0 kg (1,715 lb) of nitrate from the perched zone. With continued extraction, additional data will be available to guide the optimization of the removal action and support final remedial options for the 200-DV-1 and 200-BP-5 OUs.

5.3 Quality Assurance/Quality Control

QC requirements for perched water sampling are specified in the removal action SAP (Table 2-4 of DOE/RL-2014-51). Field QC samples were collected to evaluate cross-contamination potential and provide information pertinent to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of analytical data. During 2016, QC samples were collected according to the SAP. QA/QC sampling and analysis of the 200-DV-1 OU perched water wells information is provided in Appendix E of DOE/RL-2016-67, including a view of QA/QC issues that may affect data interpretation in this report.

5.4 Removal System Costs

The actual cost breakdown for perched water removal action activities for 2016 is provided in Table 5-10. The costs in Table 5-10 are burdened. Based on a total of 224,434 L of perched water extracted, the removal system costs in 2016 were $13.00/L.

Table 5-10. Cost Breakdown for Perched Water Removal Action, 2016

Activity	Actual Costs ($)
Perched water project management	61,593
Design/construct new pipeline	2,104,378
Operations and maintenance *	327,790
Perched water gravity drain operations	362,020
Perched water annual report	1,472
Install perched water extraction well system	59,321
Total	**2,916,573**

* The O&M cost is an apportionment of the overall 200 West P&T O&M cost based on percentage of mass treated from extracted DV-1 groundwater to the total mass treated by the 200 West P&T.

5.5 Conclusions

The removal action for perched water extraction using three extraction wells was successfully implemented in 2016. The perched water extraction wells removed 224,434 L (59,289 gal) of perched water containing 11.2 kg (24.7 lb) of uranium, 0.36 g (0.01 oz) of technetium-99, and 195.0 kg (430 lb) of nitrate.

Hydraulic testing during startup of the three-well system was conducted from February through September 2016. During hydraulic testing, perched water samples were collected for analysis of uranium, technetium-99, nitrate, and other constituents specified in the sampling and analysis plan.

Two characterization boreholes (C9487 and C9488) were drilled and sampled to characterize two 200-DV-1 OU waste sites (216-B-7A&B Cribs and 216-B-8 Crib); the boreholes extended into the perched water aquifer. The results of the aquifer testing, analysis of characterization borehole data, and contaminant trends during pumping of the three extraction wells will be used to support the evaluation of the extent and thickness of the perched water zone, develop estimates of the volume of remaining perched water and the area of potential groundwater impact, and evaluate sources of contamination to the perched water.

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6 200-BP-5 Operable Unit Removal Actions

This chapter discusses a groundwater removal action at the 200-BP-5 OU. Groundwater removal in the 200-BP-5 OU began in September 2015 at well 299-E33-268 (Figures 6-1 and 6-2) as part of a treatability test (DOE/RL-2015-75). Treatment of the extracted groundwater is completed at the 200 West P&T (Chapter 2). Based on the success of the 2015 treatability test, DOE/RL-2015-75 recommended continued groundwater extraction at well 299-E33-268 until a NTCRA could be approved. The following introduction discusses the planning and documentation process used to arrive at a groundwater removal action, primary sources of groundwater contamination, removal volume of contaminated groundwater, removal activity/mass of primary contaminants and topic summary of other sections discussed in this chapter.

The B Tank Farm Complex (referred to as the B Complex) consists of a thick vadose zone (greater than 75 m [200 ft]) with a contaminated perched water horizon approximately 3 m (10 ft) above the thin unconfined aquifer. A treatability test was approved to evaluate the practicality of sustainable groundwater extraction in the shallow and discontinuous aquifer at the B Complex (DOE/RL-2010-74, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*). Extraction well 299-E33-268 was installed within the technetium-99 and uranium plume where the aquifer was approximately 2 m (7 ft) thick. Pumping rates of 568 L/min (150 gpm) produced less than 11 cm (5 in.) of drawdown at extraction well 299-E33-268 (DOE/RL-2015-75). As a result, an engineering evaluation/cost analysis (EE/CA) (DOE/RL-2015-26, *Engineering Evaluation/Cost Analysis for the 200-BP-5 Operable Unit Groundwater Extraction*) was developed in early 2016. The scope of the EE/CA (DOE/RL-2015-26) was to prevent further migration of groundwater contaminants. The removal scope, approved in December 2016 through Tri-Party signature of DOE/RL-2016-41, *Action Memorandum for 200-BP-5 Operable Unit Groundwater Extraction*, is designed to recover elevated levels of groundwater contamination while awaiting completion of the CERCLA RI/FS process and issuance of a 200-BP-5 OU ROD.

The primary sources of groundwater contamination in the B Complex are releases of the scavenged uranium recovery liquid waste and unplanned metal waste. Technetium-99, uranium, nitrate, cyanide, iodine-129, and tritium form groundwater plumes in the area. Figure 6-3 provides the extent of contaminants prior to the start of groundwater removal. These contaminants originated from releases in this area, except for iodine-129, which is associated with the Plutonium-Uranium Extraction Plant (PUREX) overlying the 200-PO-1 OU.

Through 2016, approximately 1668 million L (43.8 million gal) of contaminated groundwater has been extracted from well 299-E33-268. Groundwater sample results, collected periodically between September 2015 and December 2016, suggest approximately 1.29 Ci of technetium-99 and 14 kg of uranium have been removed from the B Complex unconfined aquifer (Figure 6-4).

Section 6.1 provides an overview of the hydraulic monitoring network for B Complex and methods of data analysis to determine capture. Sections 6.2 and 6.3 describe the 200-BP-5 groundwater extraction system design and operation of the groundwater extraction system, respectively. Section 6.4 presents the QA/QC encompassing sampling and analysis of the 200-BP-5 OU, and Section 6.5 summarizes the system costs. Section 6.6 includes the conclusions.

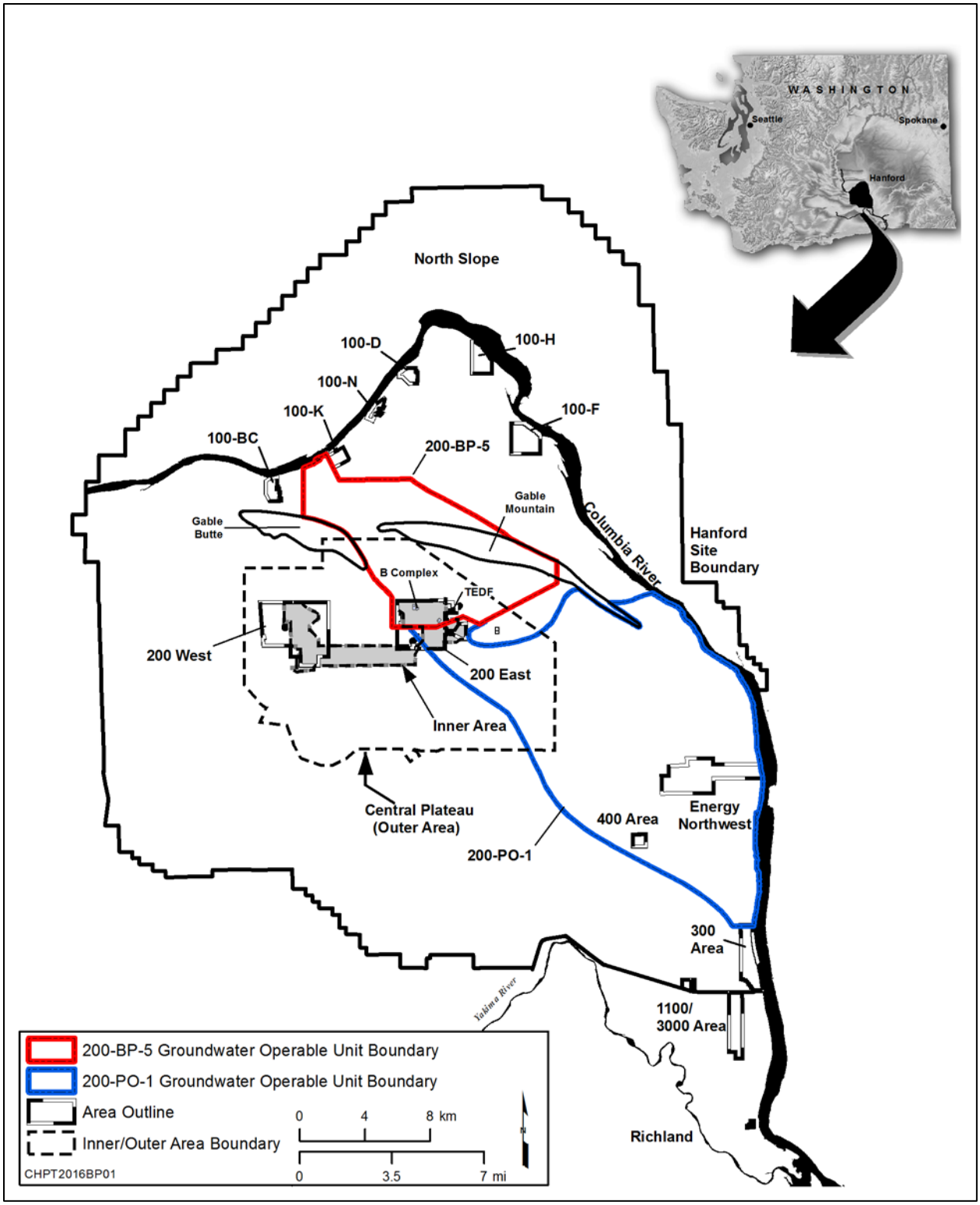

Figure 6-1. Location of the Hanford Site in Southeastern Washington State, Including the 200-BP-5 OU and 200 East Area Boundaries

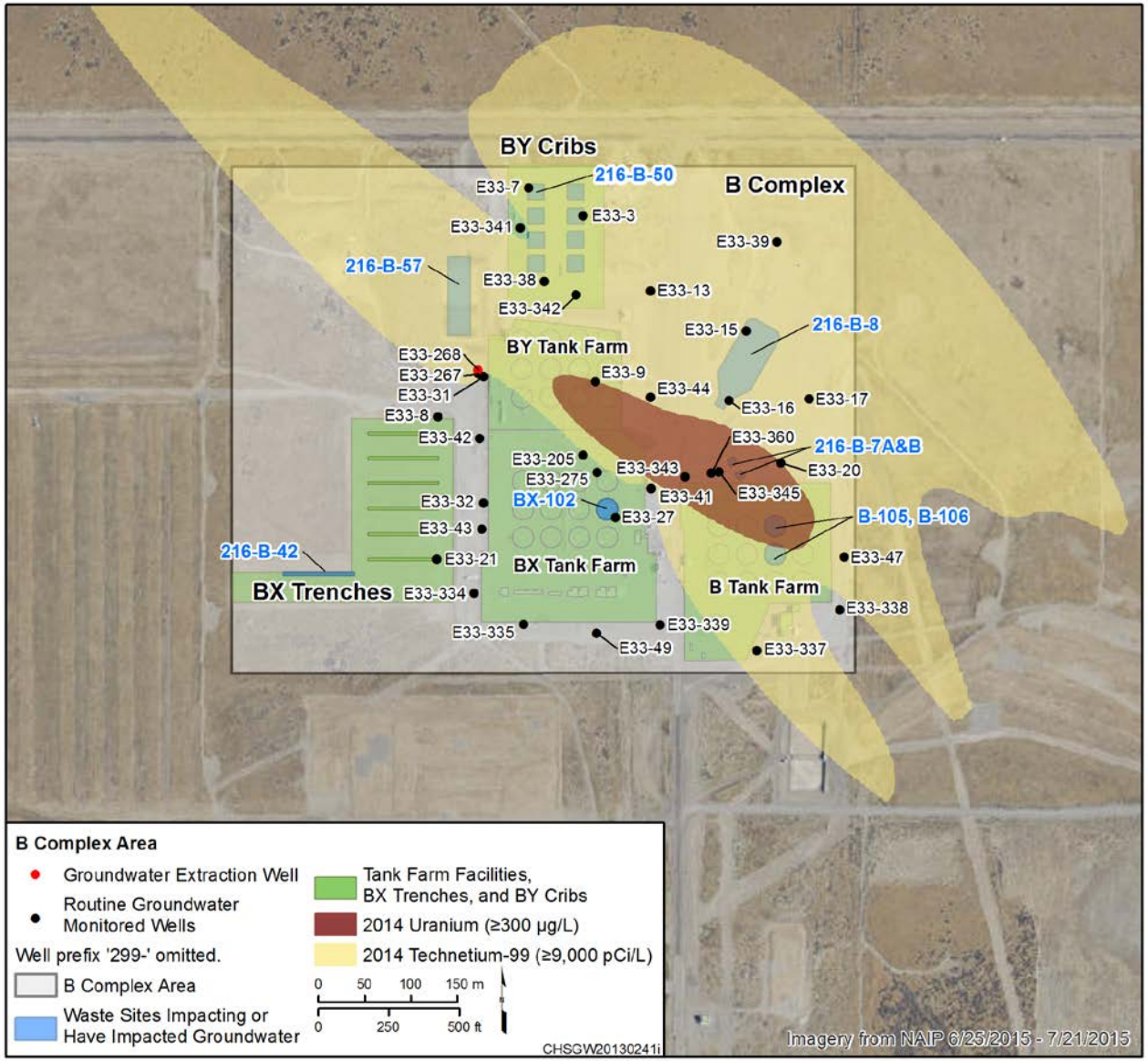

Figure 6-2. Map of the B Complex Area Illustrating Underlying Technetium-99 and Uranium Groundwater Plumes

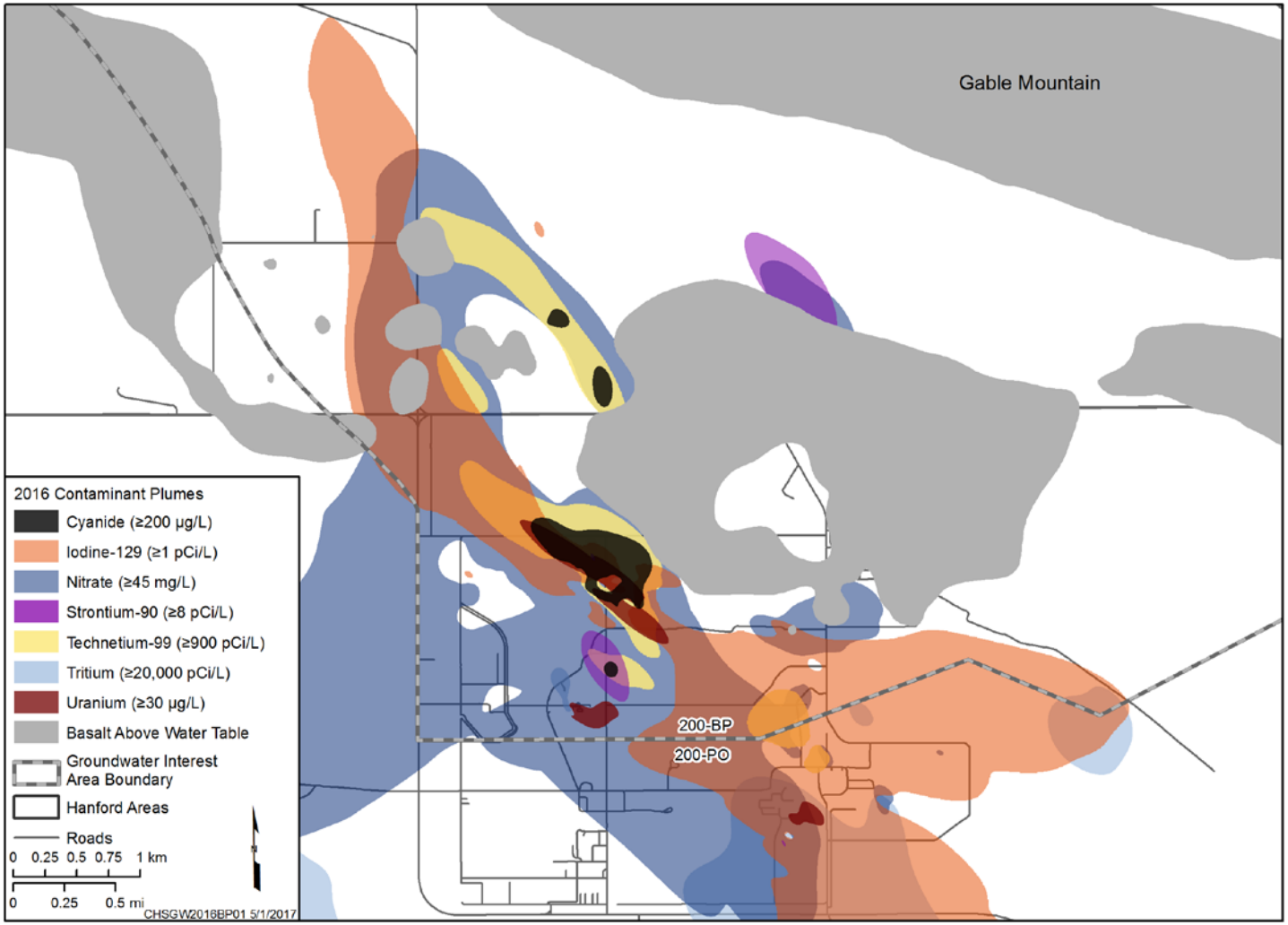

Figure 6-3. 2015 200-BP-5 OU Consolidated Plume Map

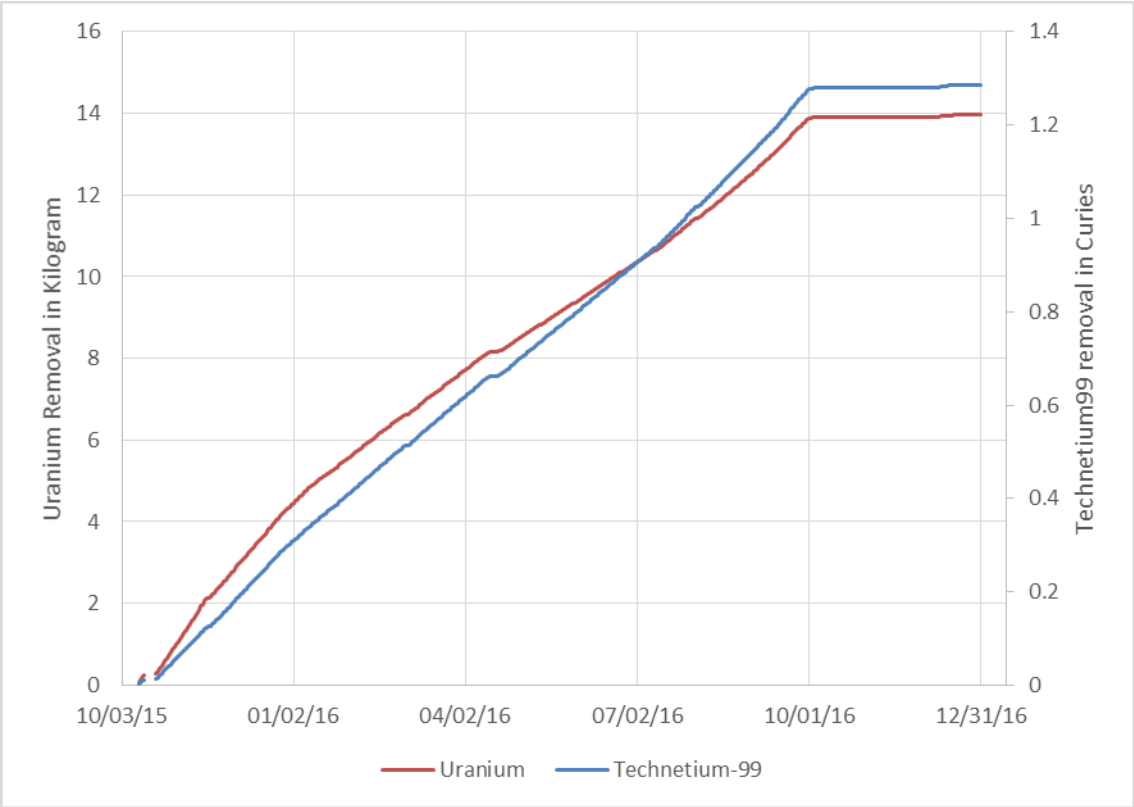

Figure 6-4. Technetium-99 and Uranium Removal Rate through 2016

6.1 B Complex Hydrogeology Overview

The B Complex hydrogeology includes a perched zone and unconfined and confined aquifers. The perched water horizon lies 3 m (10 ft) above the water table, extending along the north side of the B Tank Farm (see Figure 2-10 of DOE/RL-2011-102, *Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-DV-1 Operable Unit*), and is contaminated from a 1951 overfill event associated with tank 241-BX-102. The release consisted of 346,744 L (91,600 gal) of contaminated liquid. The derived release inventory is estimated to have released 2.27 Ci of technetium-99, 10,100 kg of uranium, 3800 kg of nitrate, and 3.85 Ci of tritium (RPP-26744). DOE is extracting water from the perched zone (Chapter 5), which is a part of the 200-DV-1 OU.

The unconfined aquifer at B Complex is impacted by past waste disposal operations and is associated with the following suprabasalt sediments: Ringold Formation (unit A), Cold Creek unit, and Hanford formation (Figures 6-5 and 6-6). Depths to the water table from land surface range from 70 m (230 ft) north of the BY Cribs to 84.5 m (275 ft) south of the B Complex (Figure 6-5). The unconfined aquifer thickness varies from less than 1 m (3 ft) north of the B Complex to more than 5 m (16 ft) to the south (Figure 6-7). More detailed descriptions of the hydrogeology of the B Complex can be found in PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*; PNNL-19702, *Hydrologic Model for the Gable Gap Area, Hanford Site*; and PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*.

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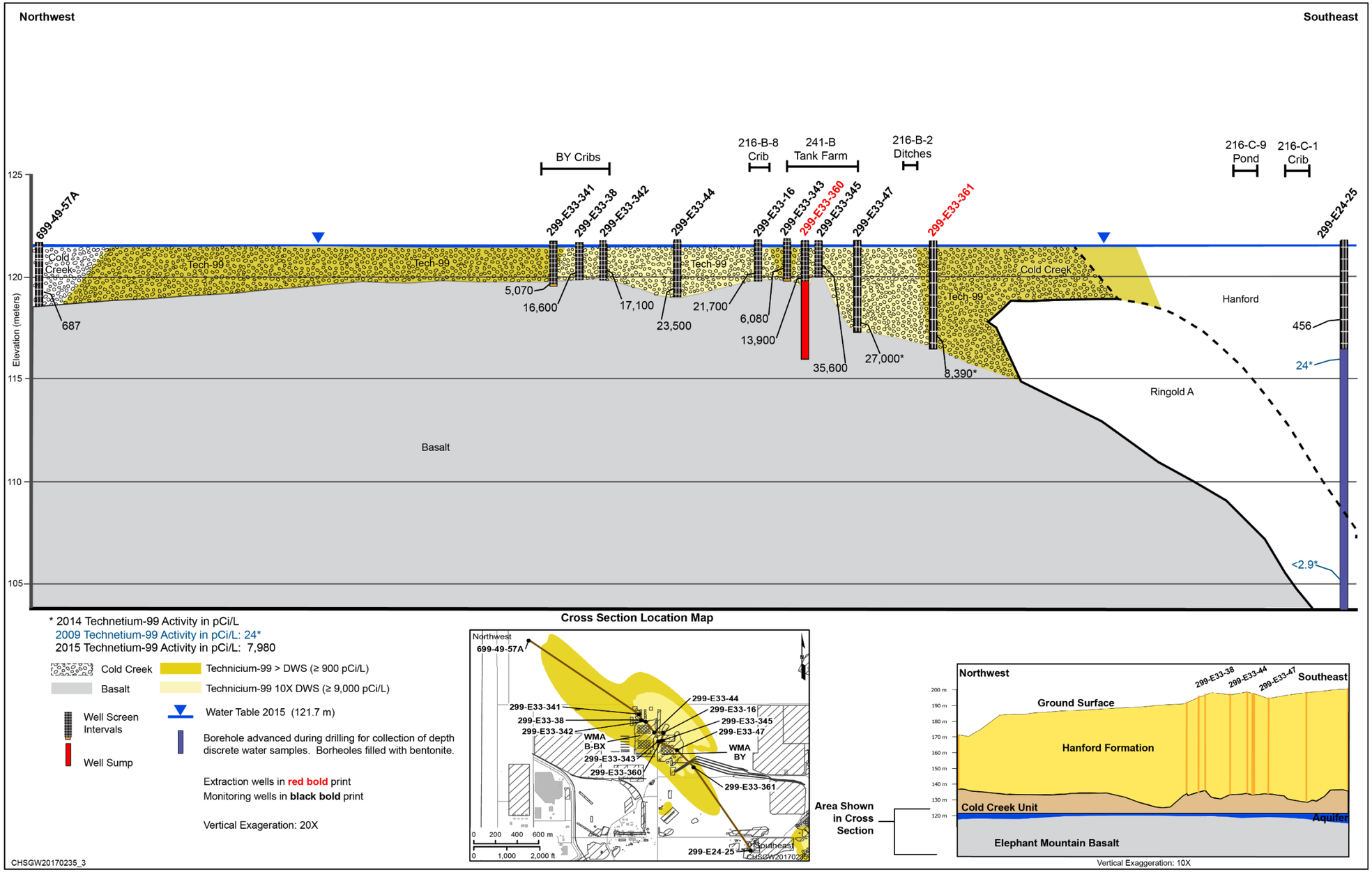

Figure 6-5. Technetium-99 2015 Conceptual Cross Section

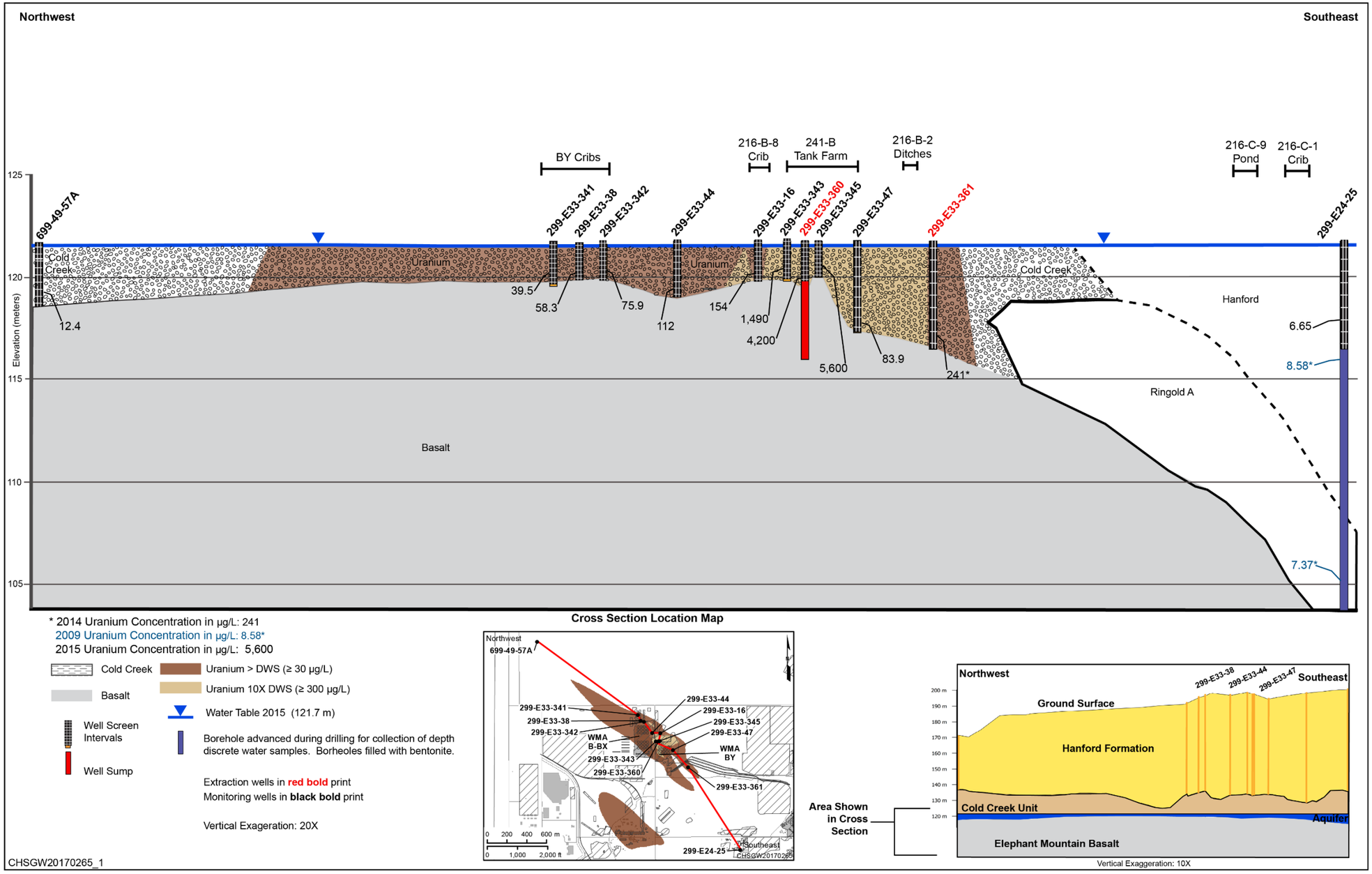

Figure 6-6. Uranium 2015 Conceptual Cross Section

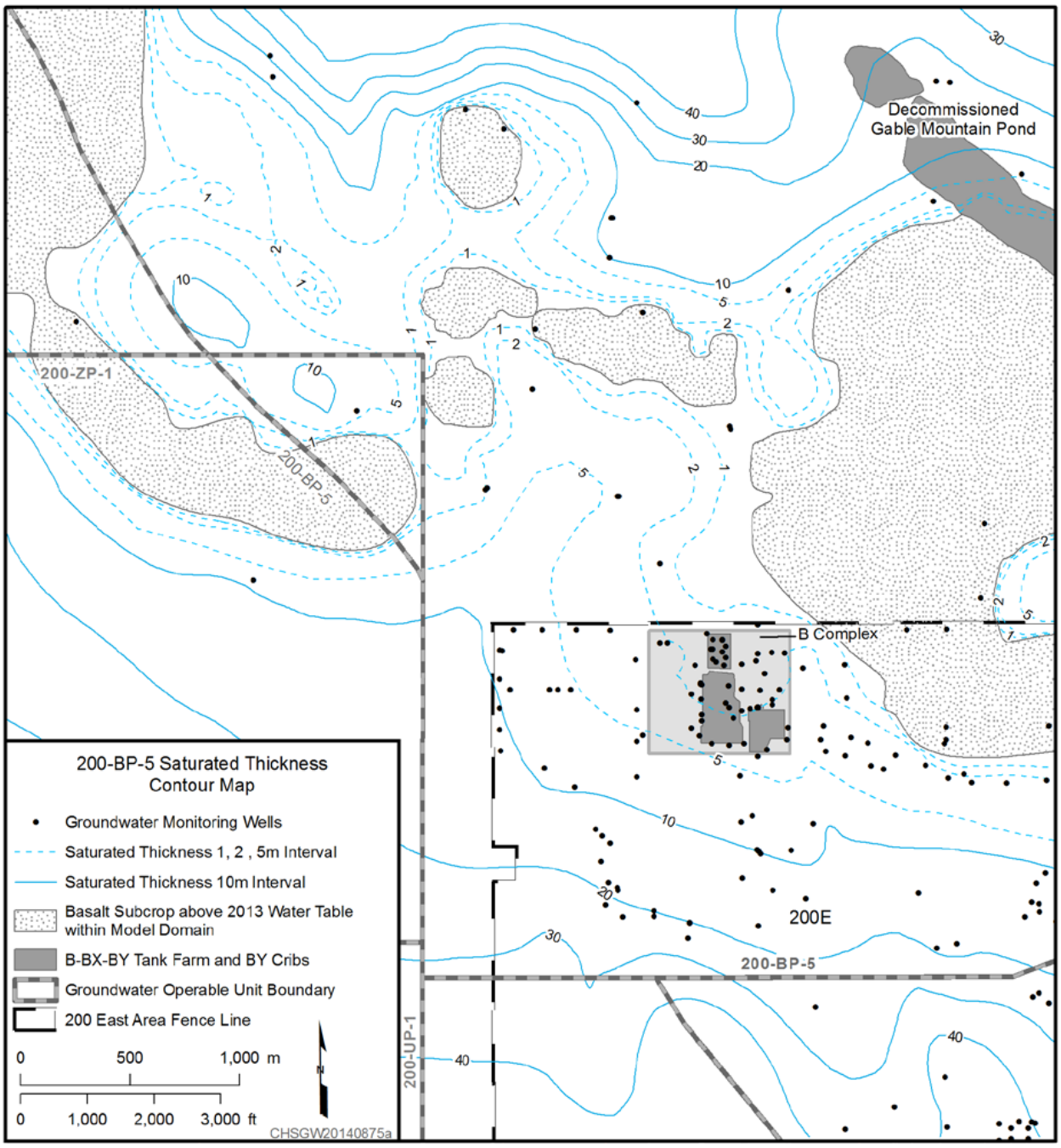

Figure 6-7. Unconfined Aquifer Saturated Thickness Contour Map in the B Complex

The groundwater gradient at the B Complex area decreases along a transmissive northwest-southeast-trending buried paleochannel (Figure 6-8, Flow Path D). Flow at the B Complex has continued to the south-southeast since July 2011. An example of the gradient is provided in Figure 6-9. The process used to complete this detailed water table gradient map is discussed in ECF-200E-16-0093, *Preparation of 200 East Area Water Table Maps for Calendar Year 2015*.

Groundwater levels since 2014 have varied based on Treated Effluent Disposal Facility (TEDF) liquid discharge volumes (Figure 6-10). The location of TEDF is provided in Figure 6-1. Extended periods of higher discharge at TEDF, as experienced in 2014 and 2015, decrease the groundwater gradient, causing slower flow rates. Groundwater contaminant concentrations appear to fluctuate in response to groundwater flow rates (Figure 6-11). After periods of high discharges and return to normal discharge rates at TEDF, groundwater levels drop significantly to levels equivalent to a 1.6 to 2 mm/month water level decline (DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*, Sections 2.7 and 2.11).

The highest levels of technetium-99 and uranium in the B Complex unconfined aquifer are beneath and downgradient of ongoing sources of groundwater contamination: BY Cribs and an unplanned 1951 metal waste release. These plumes extend to the northwest and southeast within an ancestral Columbia River paleochannel that incised Ringold deposits. Due to the high concentrations of nitrate, technetium-99, and uranium detected at the B Complex, groundwater is continuing to be extracted at well 299-E33-268 as part of the initial step to the removal action as explained in Chapter 6 of the 200-BP-5 action memorandum (DOE/RL-2016-41).

6.2 200-BP-5 Remedial System Design

A main component to the success of the treatability test was the ability to barometrically correct water table measurements. This correction allowed pumping-induced water level changes to be differentiated from atmospheric pressure changes as far as distant well 299-E33-342 (Figure 6-12), which increased the size of the area for which larger scale aquifer hydraulic parameters could be calculated.

DOE completed a treatability test to determine the aquifer response to sustained groundwater pumping at the B Complex (DOE/RL-2010-75). The overall objective of the treatability test was to determine whether a sufficient groundwater pumping rate could be sustained in the thin aquifer (less than 2.5 m [8 ft] thick), as a measure of the effectiveness of a P&T alternative to provide hydraulic containment and reduce the mass of the technetium-99 and uranium plumes near the B Complex (DOE/RL-2010-74). Groundwater was conveyed through a pipeline (Figure 6-13) to the 200 West treatment facility. Groundwater samples collected at the extraction well and 200 West P&T verified mass removal and treatment effectiveness. Eight local monitoring wells were used to evaluate water level changes associated with pumping at extraction well 299-E33-268 (Figure 6-12). Water level monitoring at only three of the wells showed reduced water level measurements during the 3-day and 27-day constant pumping tests at extraction rates greater than or equal to 379 L/min (100 gpm; DOE/RL-2015-75). The water level declines at these three wells stabilized within 1 day at levels less than 2 cm (1 in.) of drawdown. This minimal drawdown verified the sustainability for continuous pumping in this thin aquifer. The pumping rate, water table drawdown from static levels (pre-pumping level), radial distance from the extraction well to the observation well, and the duration of pumping (time) were used to derive aquifer transmissivity and specific yield (DOE/RL-2015-75). The hydraulic conductivity was also derived. Revised numerical model simulations using the hydraulic parameters derived from the treatability test measurements indicated a sufficiently wide capture zone viable for reduction of technetium-99 and uranium (Figure 6-14). As a result, the treatability test report (DOE/RL-2015-75) recommended the test continue until a NTCRA could be authorized.

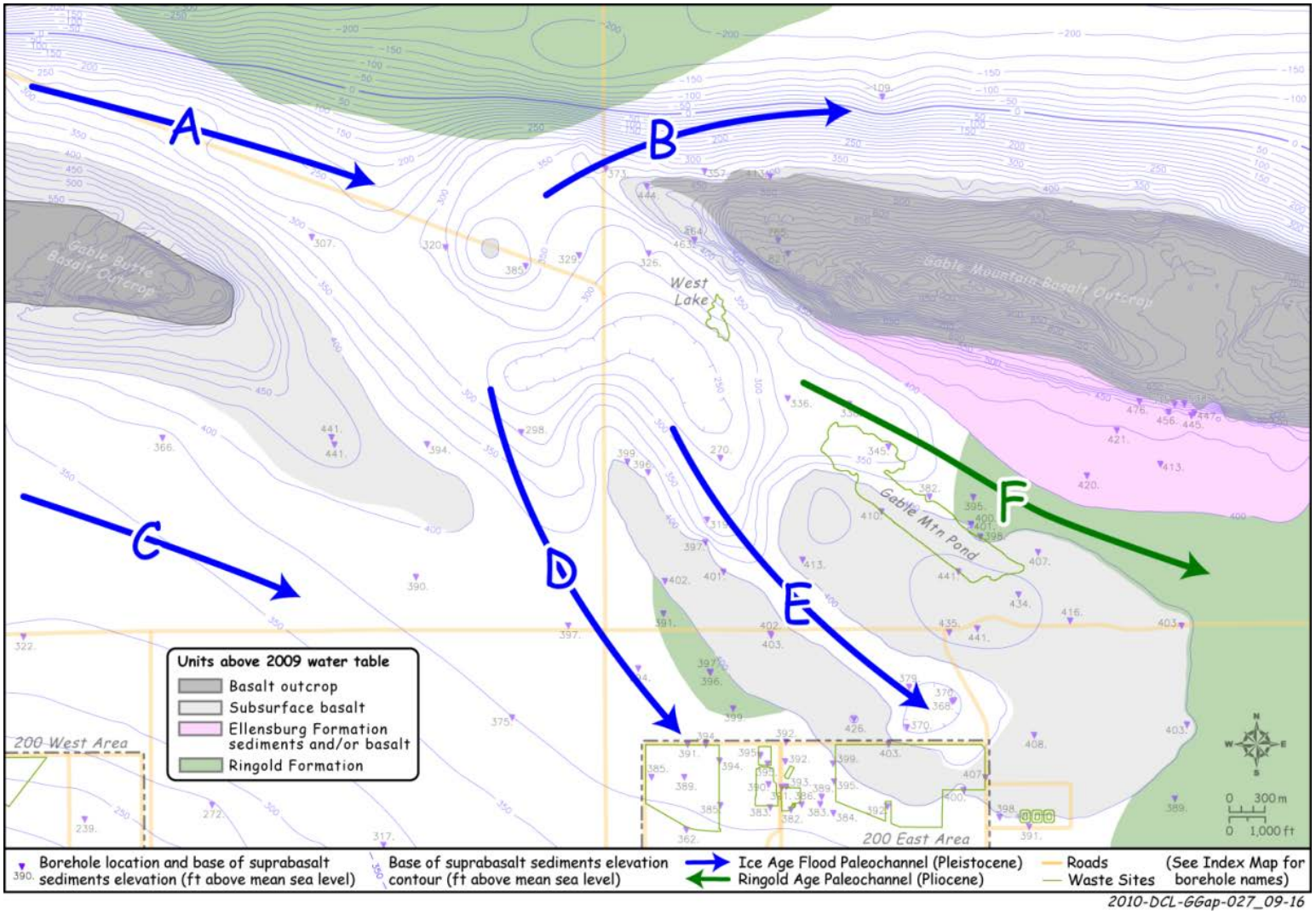

Figure 6-8. Ringold Age and Ice Age Flood Paleochannels

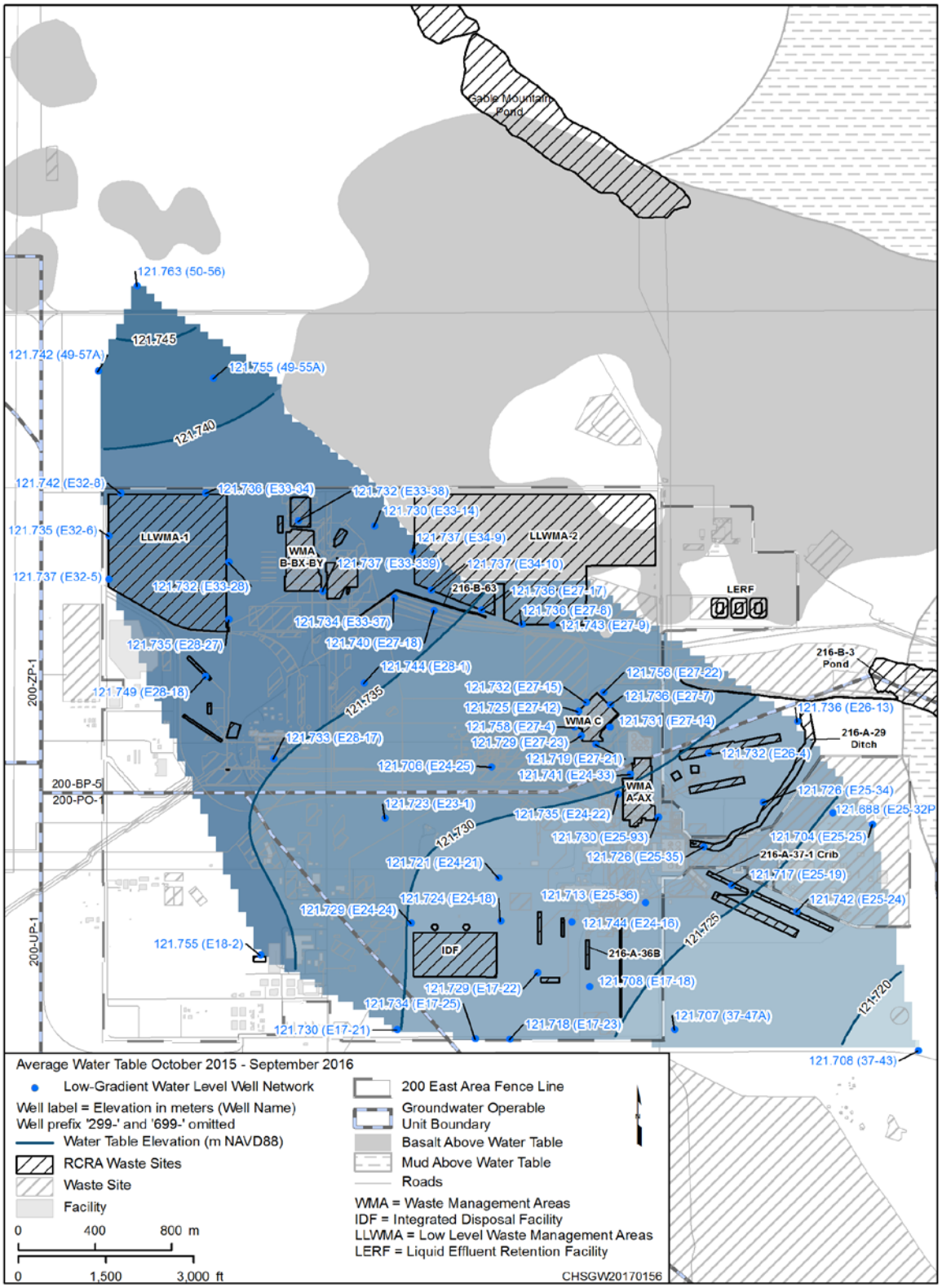

Figure 6-9. Annual Average 200 East Area Water Table Measurements and Associated Isopleths for October 2015 through September 2016

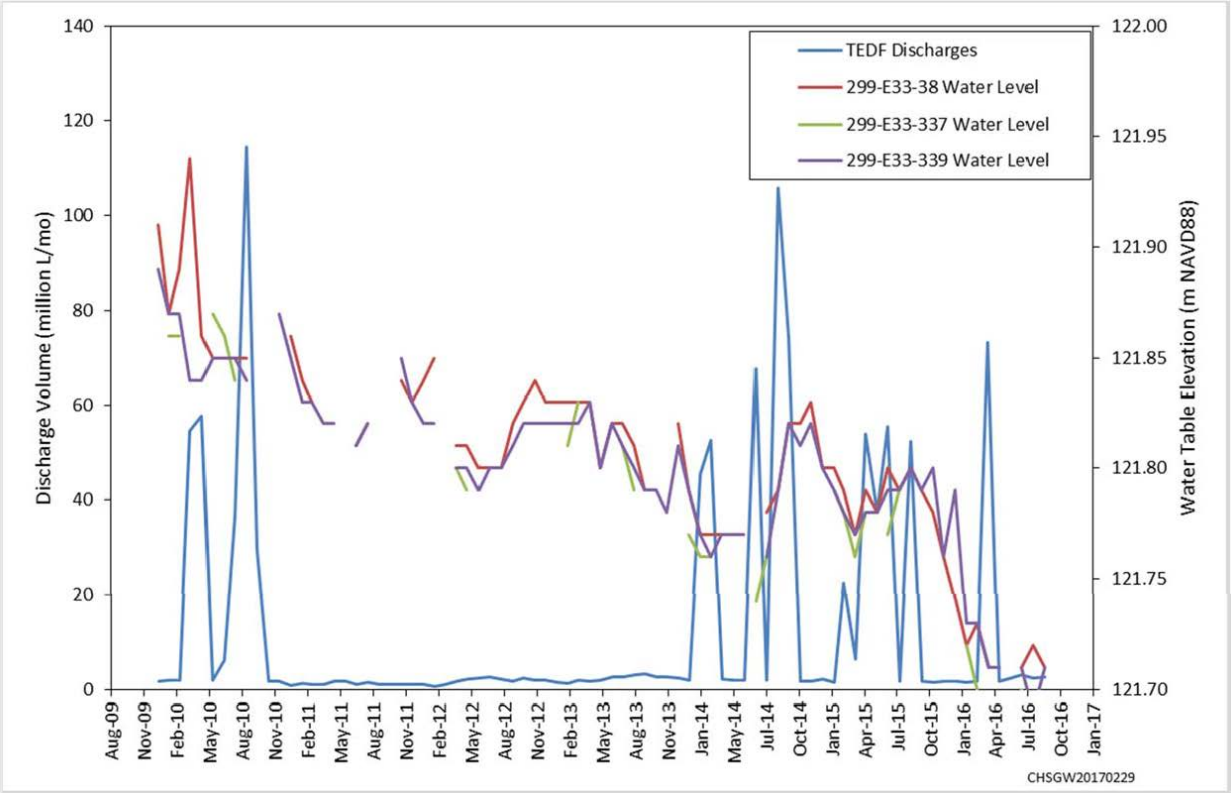

Figure 6-10. TEDF Discharges and Waste Management Area B-BX-BY Water Levels

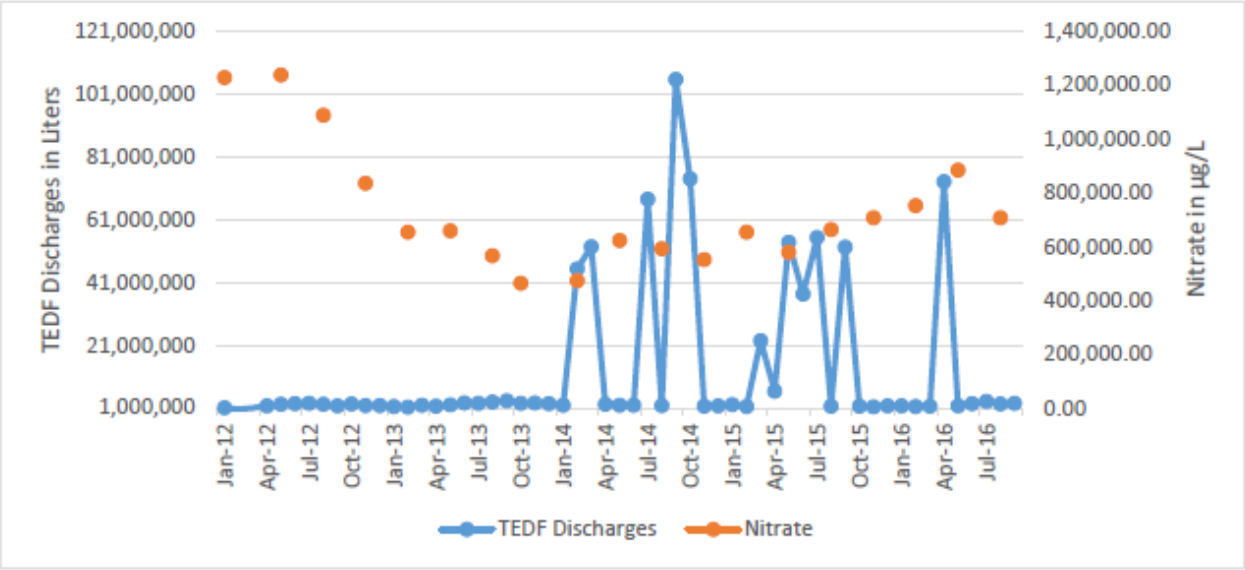

Figure 6-11. Nitrate Groundwater Concentration Variability Beneath the BY Cribs Compared with TEDF Discharge Variability

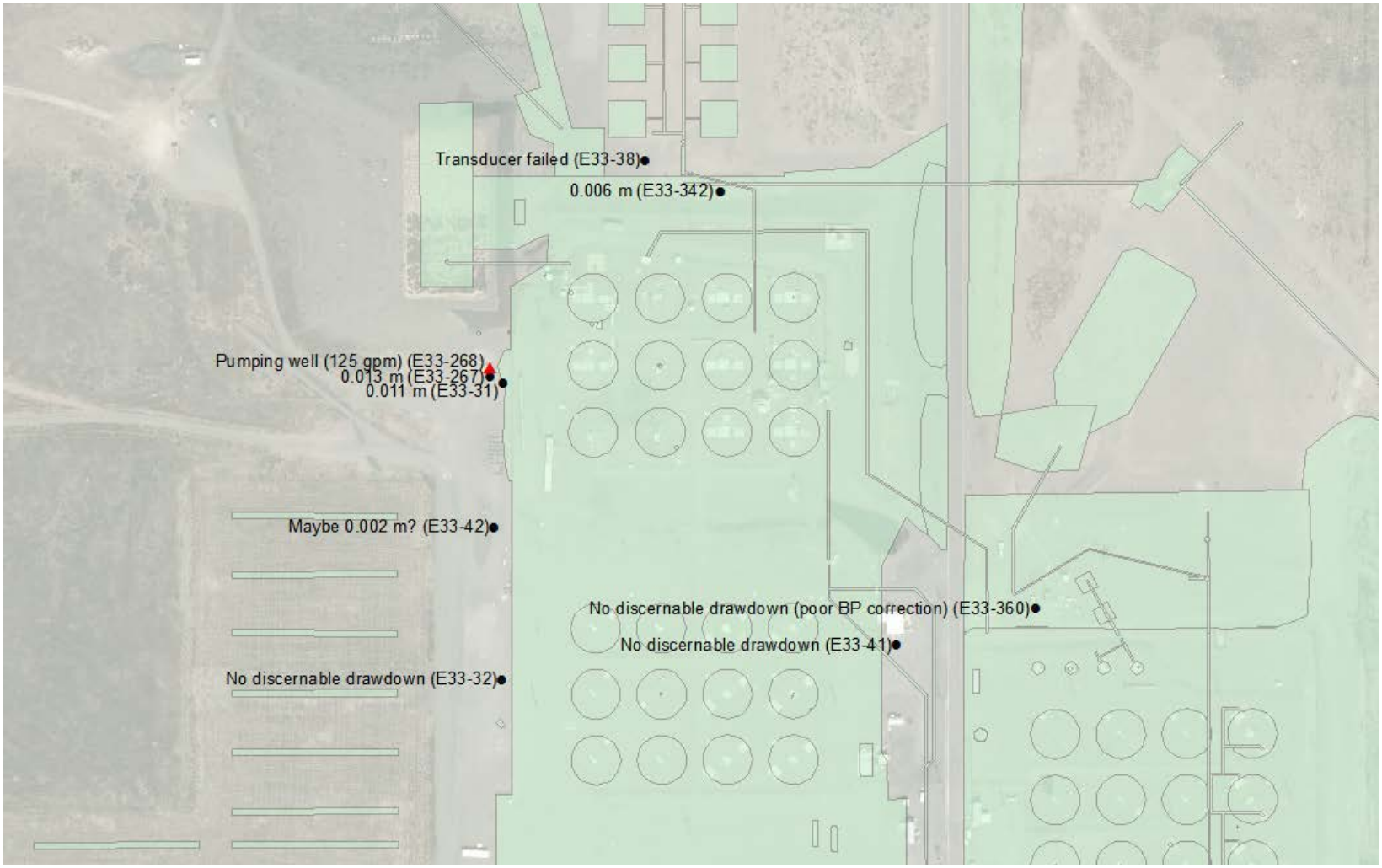

Figure 6-12. Final Drawdown Measurements for the 3-Day Constant-Rate Test at 473 L/min (125 gpm)

Figure 6-13. Diagram of the Conveyance Pipeline from Extraction Well 299-E33-268 to the 200 West P&T Facility

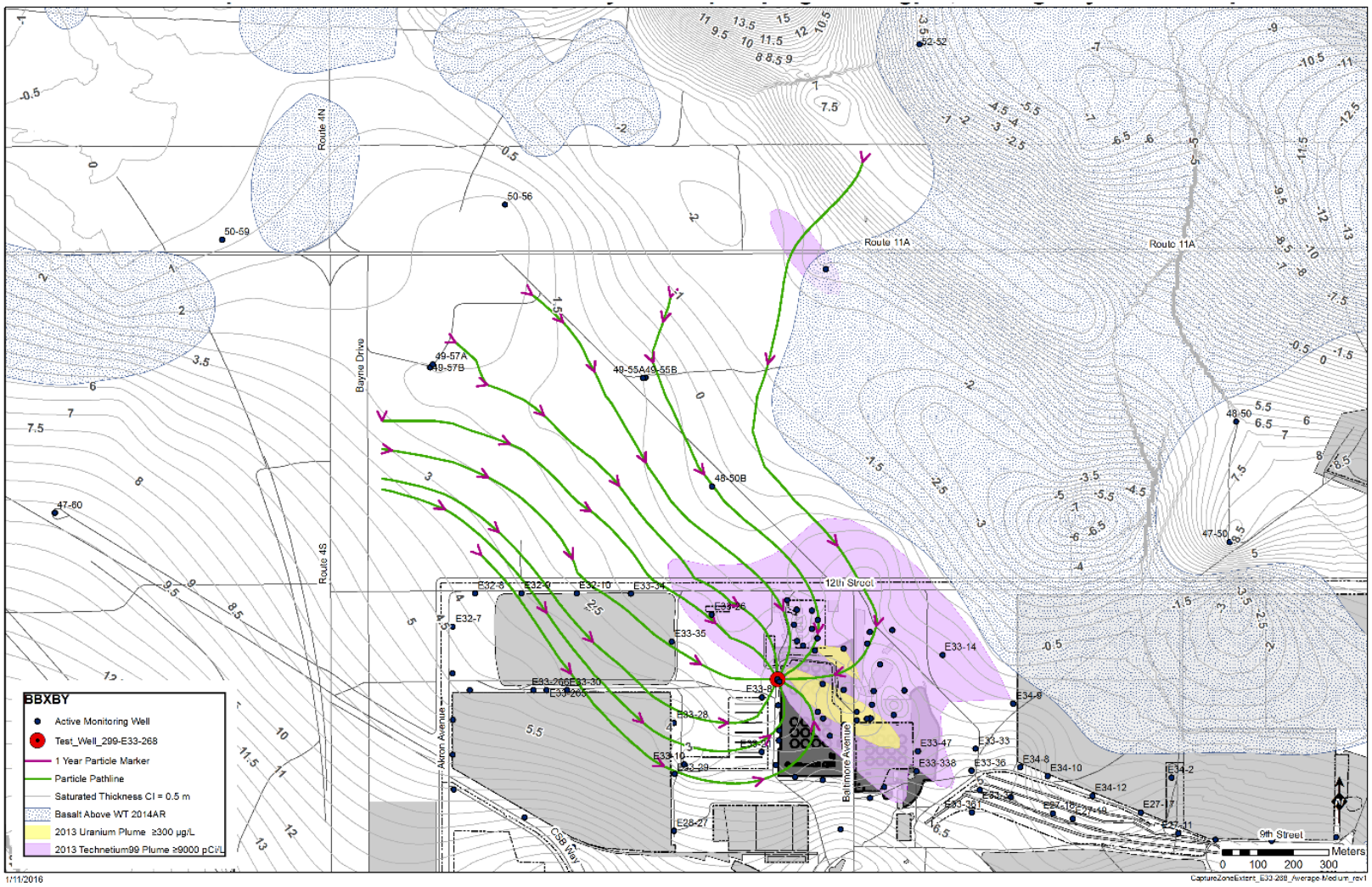

Figure 6-14. Simulated Capture Zone within the Unconfined Aquifer at 379 L/min (100 gpm) Using Average Aquifer Hydraulic Properties from Treatability Test Results

The EE/CA (DOE/RL-2015-26) evaluated the scope of work for the NTCRA including removal action alternatives, effectiveness, implementability, and cost. DOE, EPA, and Ecology used the EE/CA (DOE/RL-2015-26) as the basis for recommending a NTCRA at the B Complex. The action memorandum (DOE/RL-2016-41) documented approval of the NTCRA in December 2016 and committed to extracting contaminated groundwater from the existing extraction well 299-E33-268 (Figure 6-2) and up to three additional wells (Figure 6-5). In October2016 the system went offline to add extraction well 299-E33-360.

6.3 Remedial System Operation

The B Complex groundwater extraction system operated 80% of the time during 2016. Nonoperational time included system maintenance and expansion, and frozen extraction piping. Water was pumped from the aquifer for 287 days during 2016.

Data used to monitor the removal system consisted of flow rates from the extraction well, analytical sample results from the extraction well, and influent sample results at the 200 West P&T.

6.3.1 Extraction Well Flow Rates

Daily average flow rates for extraction well 299-E33-268 are shown in Figure 6-15. The cumulative average flow rate during the year was 242 L/min (64 gpm). This average rate was within the 189 to 568 L/min (50 to 150 gpm) extraction rate range identified in the action memorandum (DOE/RL-2016-41). The total volume of water extracted from the aquifer during 2016 was 127 million L (33.6 million gal), and the total since startup in September 2015 was 165.7 million L (43.8 million gal).

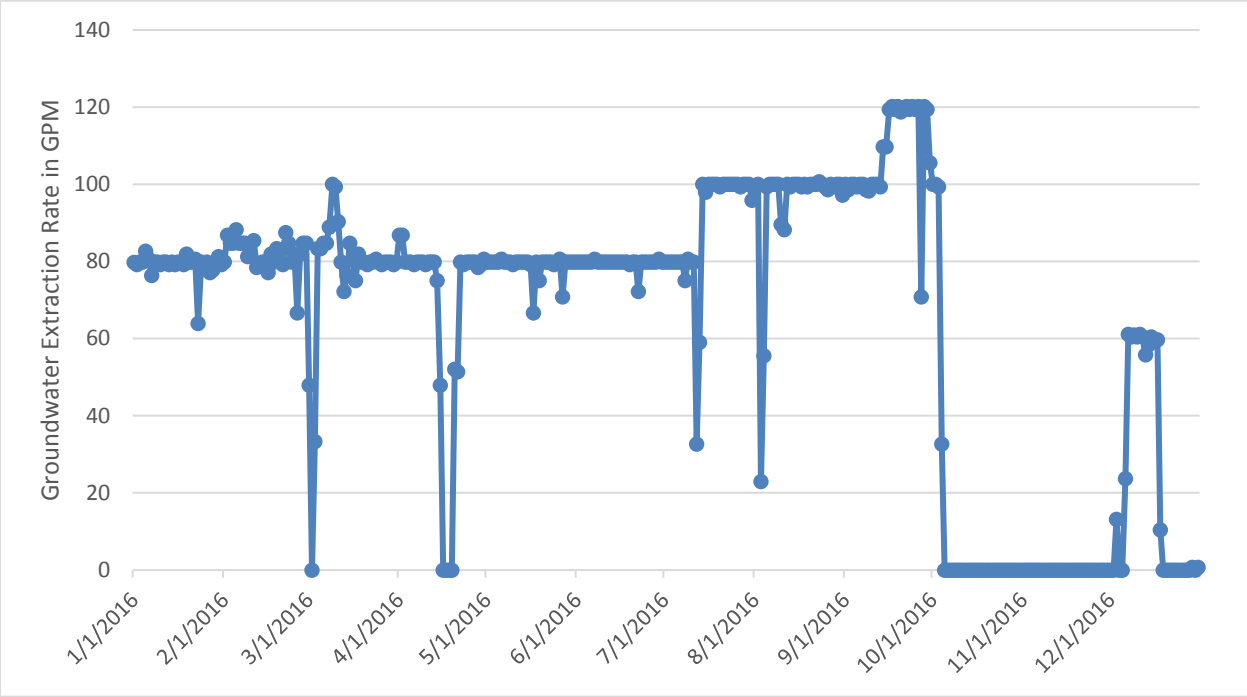

Figure 6-15. Daily Average Groundwater Extraction Rate (gpm)

6.3.2 Extraction Well Mass or Activity Removal

B Complex water samples were collected quarterly during 2016 from extraction well 299-E33-268 (Table 6-1) and the 200 West P&T. Additional samples of nitrate were collected at the 200 West P&T to ensure proper management of biological treatment.

Table 6-1. Analytical Results from Extraction Well 299-E33-268 during 2016

Date	Technetium-99 (pCi/L)	Uranium (total) (µg/L)	Nitrate (µg/L)	Cyanide (µg/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
1/11/2016	7,840	86	416,000	342	3.15	9,490
2/23/2016	--	--	419,000	--	--	--
3/15/2016	--	--	443,000	--	--	--
4/19/2016	7,810	75	421,000	365/365*	1.90/0.64	8,170
7/11/2016	7,830/7,990	63/64	--	--	--	--
8/25/2016	7,590	76	407,000	356	1.07	6,890
12/7/2016	7,540	53	363,000	378/492	1.02	6,860

* Original sample/duplicate sample.

-- = not sampled

The sample results and the extraction well flow rates were used to estimate the total mass (or activity) of the primary constituents (technetium-99 and uranium) as well as the secondary constituents (cyanide, iodine-129, nitrate, and tritium) removed from the aquifer. As of December 31, 2016 the total estimated removal of technetium-99 and uranium from the aquifer since the test began in September 2015 was 1.29 Ci and 14 kg, respectively (Figure 6-4). In 2016, 0.98 Ci of technetium-99 and 9.6 kg of uranium were removed (Table 6-2).

Table 6-2. 2016 Contaminant Mass (or Activity) Removed from the Aquifer by Extraction Well 299-E33-268

	Technetium-99 (Ci)	Uranium (total) (kg)	Nitrate (kg)	Cyanide (kg)	Iodine-129 (Ci)	Tritium (Ci)
Mass	--	9.585	53,088	45.52	--	--
Activity	0.984	--	--	--	1.64E-04	1.0

-- = not calculated

6.3.3 Water Level Monitoring

Water level monitoring is performed to evaluate the effect of the B Complex groundwater extraction system on the water table and effectiveness of the system in capturing the contaminant plumes. The following subsections describe the data interpretation for 2016.

6.3.3.1 Water Level Measurements

Groundwater gradient and flow direction were inferred using a low-gradient monitoring network across the 200 East Area, as discussed in SGW-58828, *Water Table Maps for the Hanford Site 200 East Area, 2013 and 2014*, and ECF-200E-16-0093. A 12-month rolling average calculation, from October 2015 through September 2016 was used to derive the regional water table gradient (Figure 6-9). The resulting groundwater gradient was 1.06×10^{-6} m/m, dipping to the southeast, and the estimated groundwater flow rate was 0.09 m/d (0.3 ft/d).

In 2016, ECF-200E-16-0093 was released. This document discussed how the use of water level data to determine groundwater flow directions in the 200 East Area has been problematic because of a very low hydraulic gradient magnitude combined with a relatively large depth to water. This results in a low signal-to-noise ratio in the water level elevation measurements, which makes it difficult to determine the hydraulic gradient. This problem was overcome at certain RCRA facilities in the 200 East Area through improving the accuracy of the water level measurements (by resurveying well casing elevations with greater precision, performing borehole deviation surveys [i.e., determining the difference from true vertical], and analyzing barometric pressure effects) and analyzing the data by trend surface analysis (i.e., least squares fit of a plane to the measurements; SGW-54165, *Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site*). However, other facilities were still problematic because of either their small areal extent or a spatial distribution of wells not suitable for trend surface analyses (i.e., the wells occur mostly along a line). To address sites throughout the 200 East Area, a regional 52-well, low-gradient monitoring network was created from existing groundwater wells. The data were analyzed by generating digital grids of the water table. The gridding method was inverse distance to a power set to emphasize spatial averaging. Data for each well were averaged over a yearly period, producing contour lines representing the underlying trend in the data (SGW-58828). Using this technique has provided a repeatable process in which the results are in reasonable agreement with plume movement and direction.

6.3.3.2 Hydraulic Capture Analysis

Capture zone analyses were completed for the various pumping rates and hydraulic properties as discussed in DOE/RL-2015-75. The pumping rates evaluated included 189, 379, and 586 L/min (50, 100, and 150 gpm). When evaluating the difference between capture zones there was little noticeable difference (Figures 6-14 and 6-16). Figure 6-16 shows the numerical model of capture at a pumping rate of 50 gpm, slightly lower than the average 242 L/min (64 gpm) pumping rate during 2016. This capture analysis appears to coincide with the estimated capture as depicted in Figure 6-17.

6.3.4 Contaminant Monitoring

This section summarizes the 2016 results for groundwater sampling of the primary contaminants of concern at the B Complex, technetium-99 and uranium. The aquifer thickness and vertical distribution of these primary plumes of concern are shown in cross-section (Figures 6-5 and 6-6). Discussions of the 2016 nature and extent of other plumes within the OU are provided in DOE/RL-2016-67.

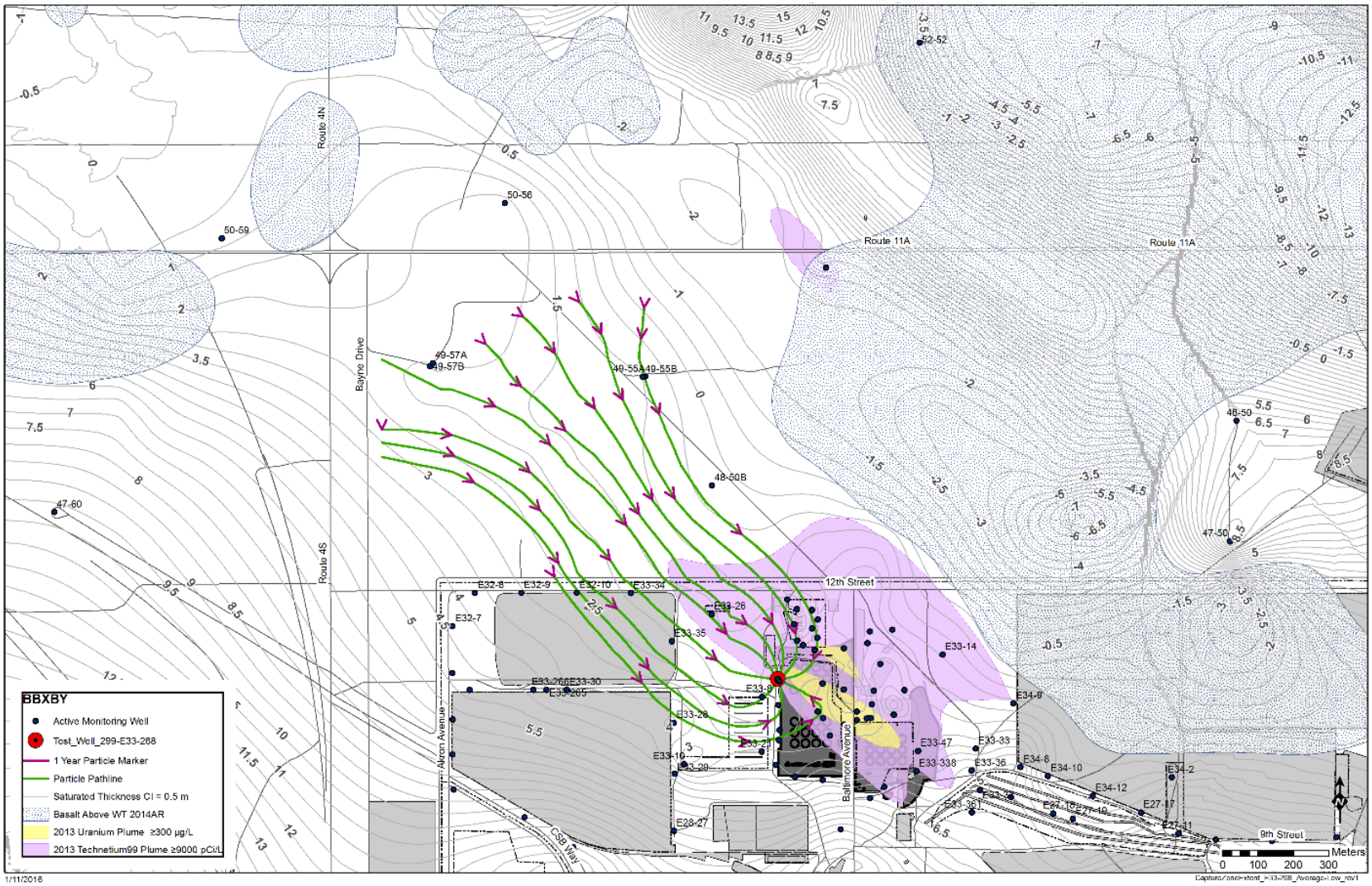

Figure 6-16. Simulated Capture Zone within the Unconfined Aquifer at 189 L/min (50 gpm) Using Average Aquifer Hydraulic Properties from Treatability Test Results

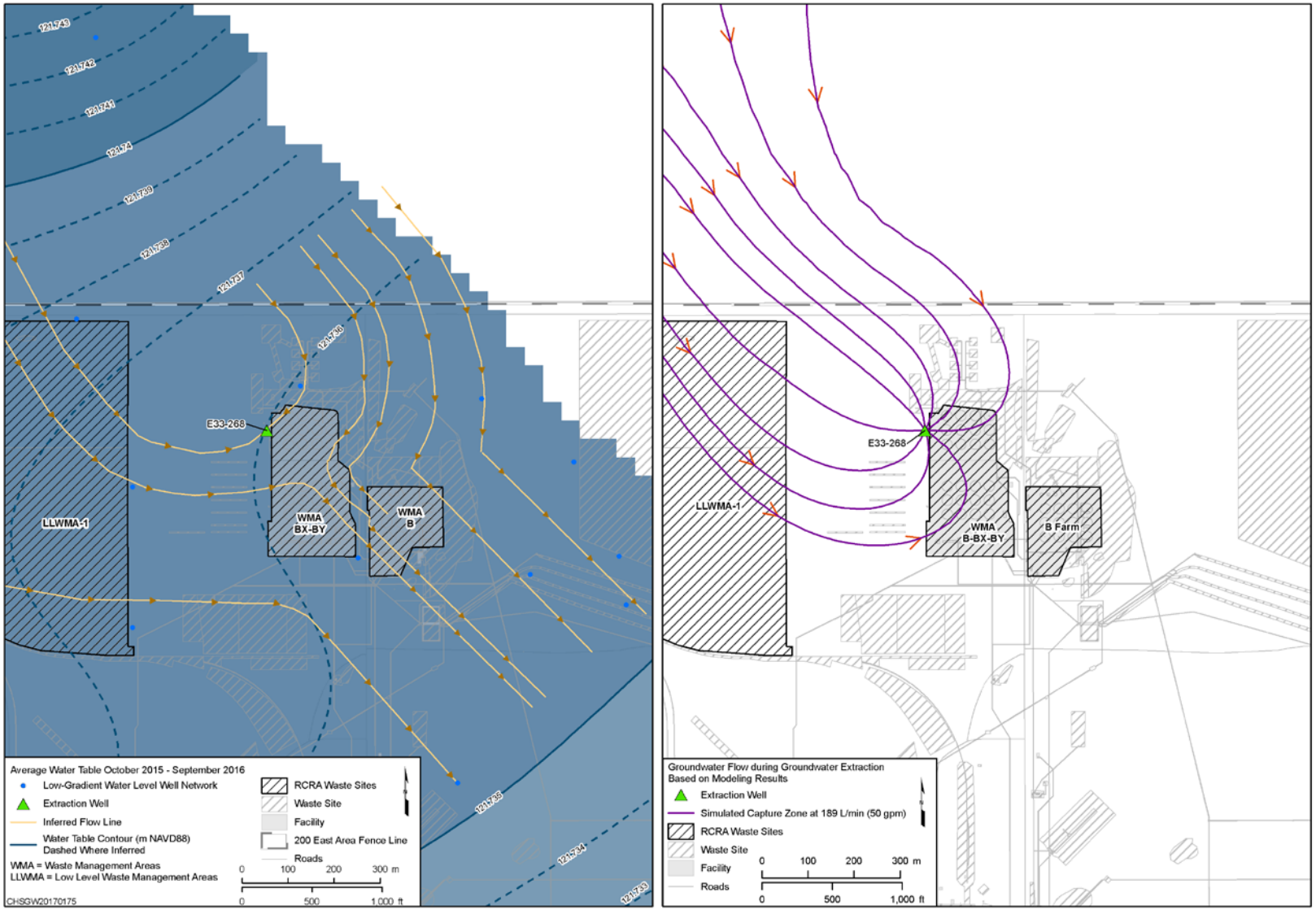

Figure 6-17. Inferred Groundwater Flow Pathways Based on Water Table (Left Panel) and Modeling (Right Panel)

The 2015 and 2016 contaminant concentrations are compared for evaluation of the effectiveness of contaminant removal associated with pumping from extraction well 299-E33-268. Trend plots at various wells are also used to show concentration/activity changes that may have been effected by pumping from extraction well 299-E33-268. Because of the thin aquifer, modest southeast average flow rate (0.09 m/d [0.3 ft/d]), and general concentration declines along the periphery of the plume, differentiating the change in concentration from groundwater extraction is based on an increased decline in concentrations trends. In the following subsections, 2016 sample results for technetium-99 and uranium are presented and compared to baseline concentration trends. Depictions of plumes are based on annual average concentrations in the wells and are the same as those presented in DOE/RL-2016-67.

6.3.4.1 Technetium-99 Monitoring Results

The 2015 and 2016 technetium-99 plume extents are compared for evaluation of the effectiveness of contaminant removal associated with pumping from extraction well 299-E33-268. Trend plots at various wells are used to show activity changes that may have been effected by pumping from extraction well 299-E33-268.

Comparison of the 2015 and 2016 technetium-99 plumes shows a decrease in activity to the southeast of extraction well 299-E33-268 (Figure 6-18). Technetium-99 activity at wells 299-E33-31, 299-E33-41, and 299-E33-42 located south of extraction well 299-E33-268 decreased below the DWS in 2016 (Table 6-3). Technetium-99 trend plots associated with wells 299-E33-31, 299-E33-41, and 299-E33-42 show significant decreases starting in later 2015 and extending below the DWS in late 2016 (Figure 6-19). The increase at well 299-E33-31 in late 2016 is associated with migration of the technetium-99 plume from extraction well 299-E33-268, approximately 30 days after the extraction well pumping was shut down for system expansion. Three additional wells (299-E33-3, 299-E33-14, and 299-E33-39) located to the northeast of extraction well 299-E33-268 appear to define a possible boundary of influence from extraction well 299-E33-268. Figure 6-20 shows a similar technetium-99 trend at wells 299-E33-14 and 299-E33-39 until late 2016. In 2016, technetium-99 activity increased at well 299-E33-14 while decreasing at well 299-E33-39. Well 299-E33-39 is near the numerical model simulation capture zone boundary defined in Figure 6-14. Well 299-E33-3, located under the northeast part of the BY Cribs, also showed a significant decrease in later 2016 (Figure 6-20). Although well 299-E33-3 has shown significant concentration changes in the past, it also falls within the numerical model simulation capture zone boundary defined in Figure 6-14. Expansion and continued operation of the system in 2017 is expected to reduce technetium-99 levels to the east of the 241-BY Tank Farm significantly.

Comparison of the 2015 and 2016 technetium-99 plumes shows no change in the southeast extent of the plume (Figure 6-18). The removal action work plan will address this portion of the plume by proposing expansion of the extraction system to include well 299-E33-361 (Figure 6-5). In addition, a new monitoring well is planned to be installed beyond the estimated southeast extent of the plume to verify the geometry of the plume.

6.3.4.2 Uranium Monitoring Results

Uranium contamination in groundwater at the B Complex appears to be primarily from a 1951 unplanned release from tank 241-BX-102 located within the 241-BX Tank Farm. The 2015 and 2016 uranium plume extents are compared for evaluation of the effectiveness of contaminant removal associated with pumping from extraction well 299-E33-268. Trend plots at various wells are used to show concentration changes that may have been effected by pumping from extraction well 299-E33-268.

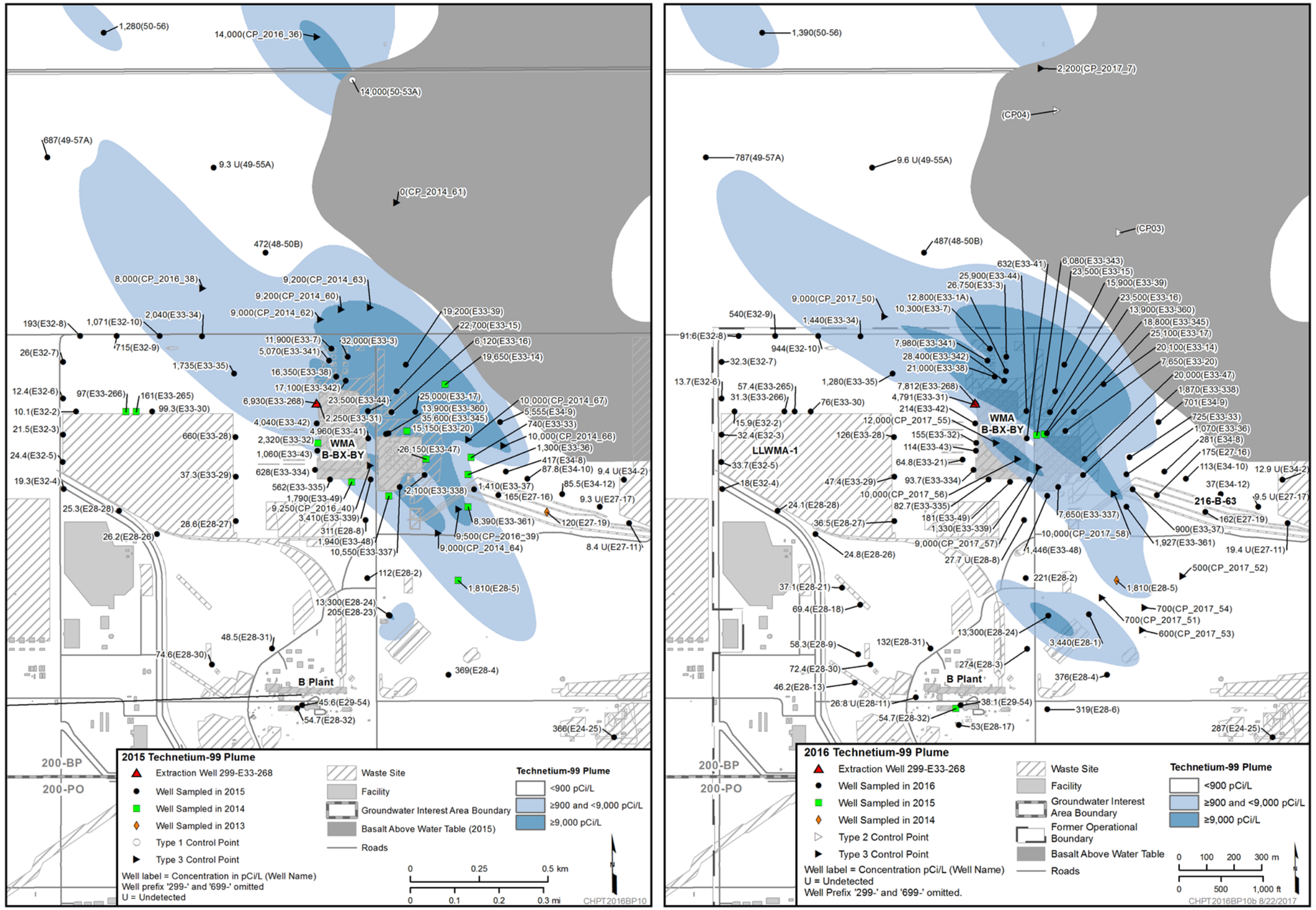

Figure 6-18. Comparison of 2015 and 2016 B Complex Technetium-99 Plume

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Table 6-3. Technetium-99 Levels in Wells South of Extraction Well 299-E33-268

Well Name	Technetium-99 Concentrations (pCi/L)				
	8/5-6/2014 (prior to pumping at 299-E33-268)	8/5/2015 (2 months prior to pumping at 299-E33-268)	11/23/2015 (1.5 months after pumping started at 299-E33-268)	8/11-16/2016 (11 months after pumping started at 299-E33-268)	11/4/2016 (1 month after pumping stopped at 299-E33-268)
299-E33-31	5,310	--	2,250	551	9,030
299-E33-41	8,270	4,960	--	632	--
299-E33-42	6,130	4,040	--	214	--

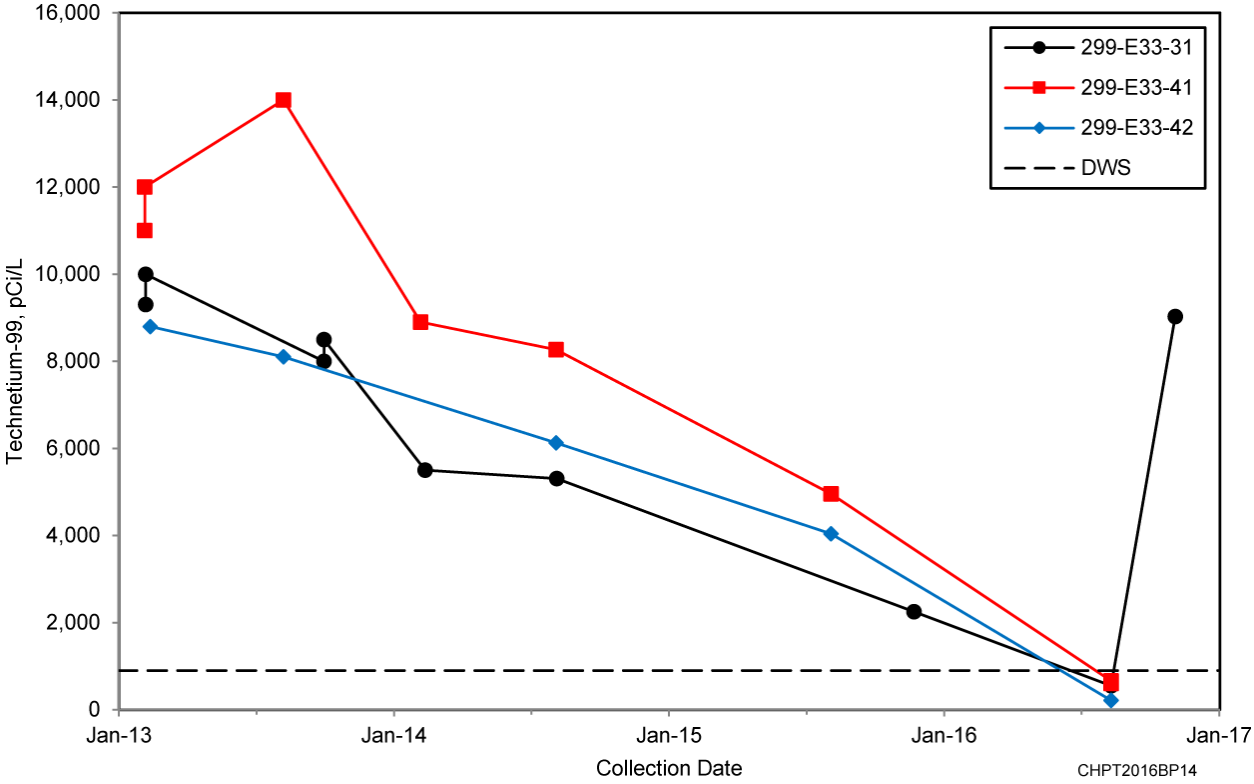

Figure 6-19. Technetium-99 Trend Plots for Wells 299-E33-31, 299-E33-41, and 299-E33-42 Located South of Extraction Well 299-E33-268

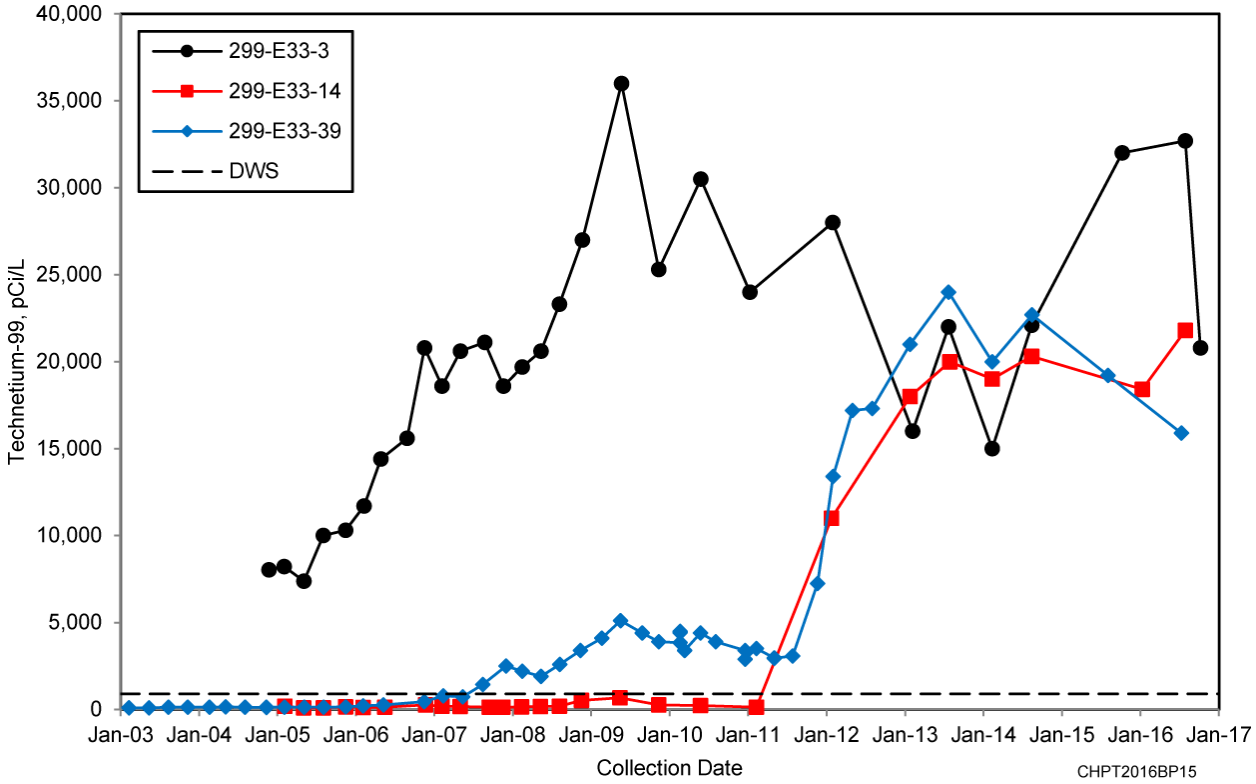

Figure 6-20. Technetium-99 Trend Plots for Wells 299-E33-3, 299-E33-14, and 299-E33-39 Located Northeast of Extraction Well 299-E33-268

Comparison of the 2015 and 2016 uranium plumes shows a significant decrease in concentration to the southeast of extraction well 299-E33-268 (Figure 6-21). Two wells south-southeast of extraction well 299-E33-268 decreased below the DWS in 2016. Uranium trend plots for wells 299-E33-31, 299-E33-41, and 299-E33-42 showed that the rate of decline had slowed prior to 2016 (Figure 6-22). After extraction at well 299-E33-268 began, the rate of decline increased, and by early 2016 concentrations at wells 299-E33-41 and 299-E33-42 had dropped below the DWS. By August, uranium concentrations at well 299-E33-31 approached the DWS. The increase at well 299-E33-31 in late 2016 is associated with migration of uranium from extraction well 299-E33-268.

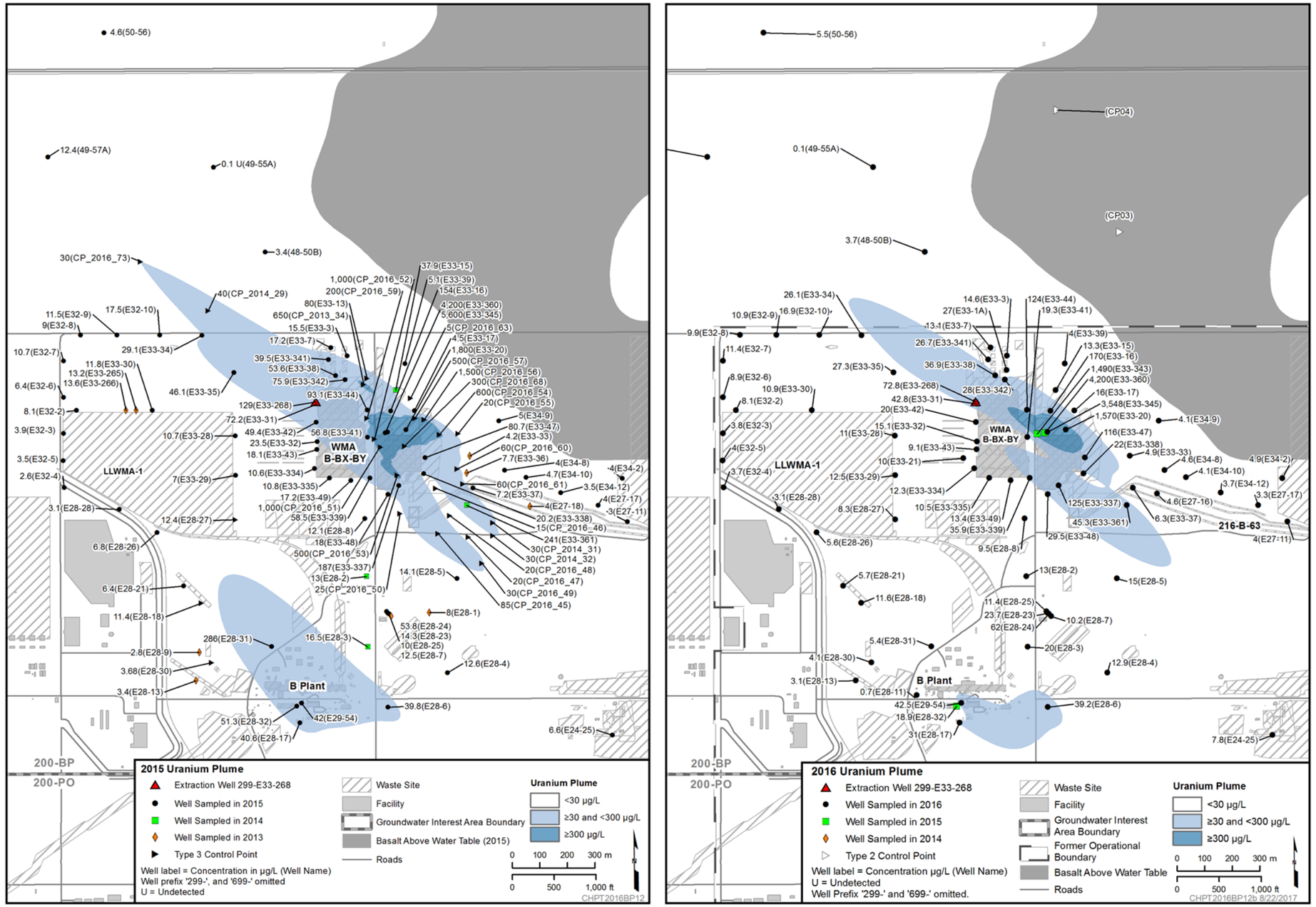

Figure 6-21. Comparison of 2015 and 2016 B Complex Uranium Plume

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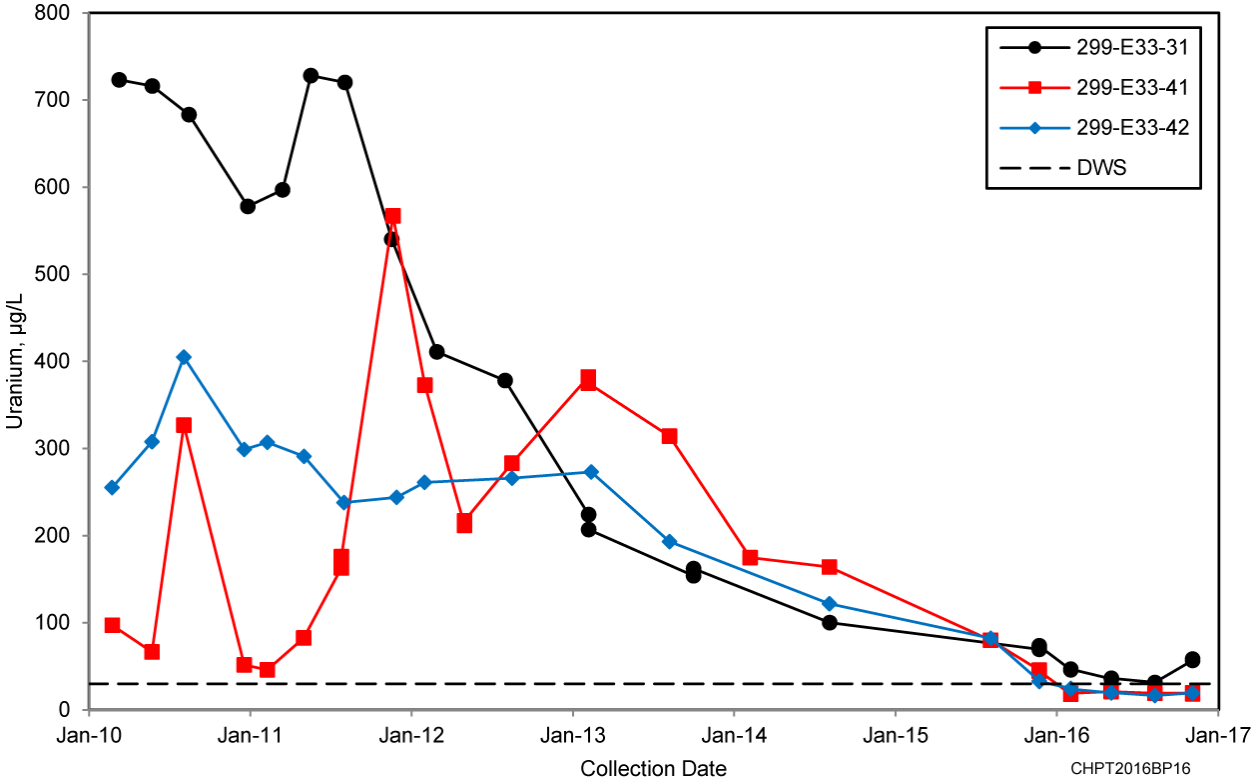

Figure 6-22. Uranium Trend Plots for Wells 299-E33-31, 299-E33-41, and 299-E33-42 Located South of Extraction Well 299-E33-268

Three additional wells (299-E33-16, 299-E33-38, and 299-E33-44) located to the northeast and east of extraction well 299-E33-268 appear to define a possible boundary of influence from extraction well 299-E33-268. Figure 6-23 shows similar uranium trends at wells 299-E33-38 and 299-E33-44 until late 2015. In 2015, uranium decreased at well 299-E33-38 while increasing at well 299-E33-44. Well 299-E33-38 is within the numerical model simulation capture zone boundary defined in Figure 6-14. Well 299-E33-44 located east of the 241-BY Tank Farm is near the numerical model simulation capture zone boundary, while well 299-E33-16 is beyond the boundary (Figure 6-14). Shortly after pumping started at well 299-E33-268, uranium concentrations at well 299-E33-44 began to increase (Figure 6-23). The concentrations at well 299-E33-44 continued to increase and peaked in August 2016. The peak concentration approached the concentration at well 299-E33-16 (Figure 6-23). The decline in November at well 299-E33-44 may be associated with shutting down pumping at extraction well 299-E33-268. Uranium concentrations at well 299-E33-16 showed no significant change between 2015 and 2016 and indicate no effect from pumping at extraction well 299-E33-268. Expansion and continued operation of the system in 2017 is expected to significantly reduce uranium levels east of the 241-BY Tank Farm.

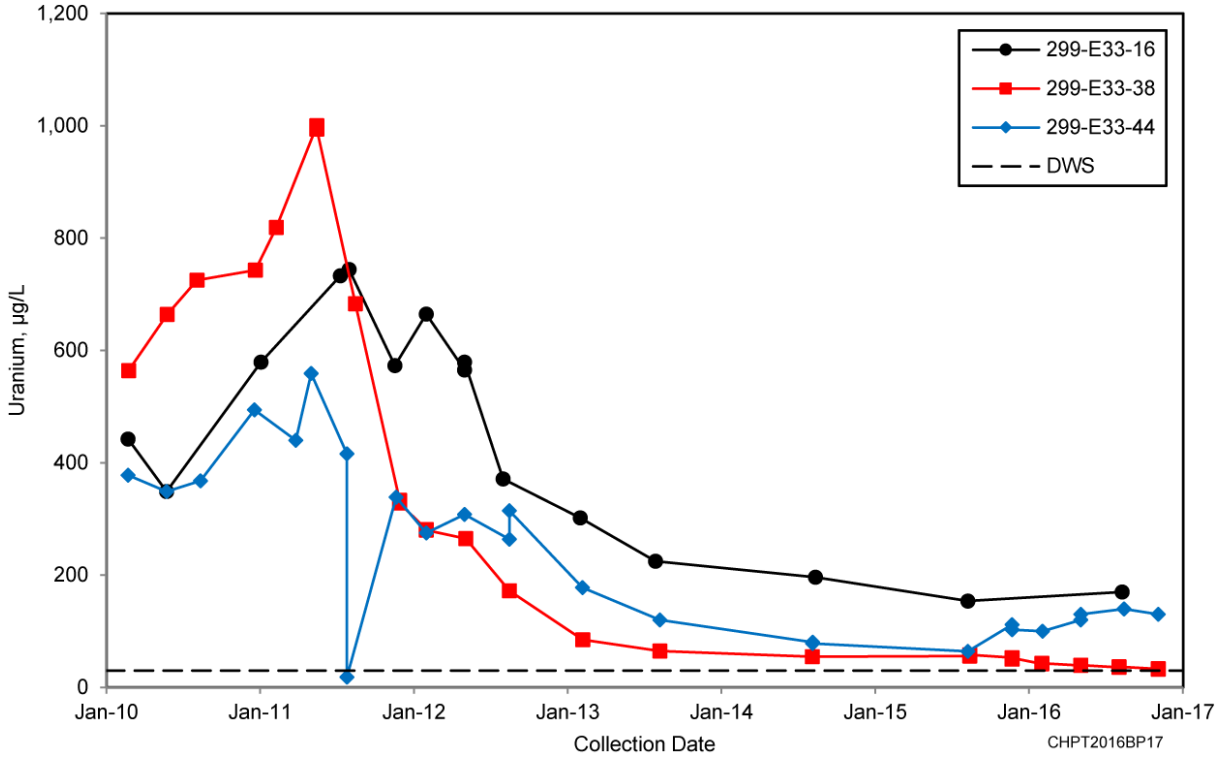

Figure 6-23. Uranium Trend Plots for Wells 299-E33-16, 299-E33-38, and 299-E33-44 Located Northeast and East of Extraction Well 299-E33-268

Comparison of the 2015 and 2016 uranium plumes show no change in the southeast extent of the plume (Figure 6-21). The removal action work plan will address this portion of the plume by proposing expansion of the extraction system to include well 299-E33-361 (Figure 6-6). In addition, a new monitoring well is planned to be installed beyond the estimated southeast extent of the plume to verify the geometry of the plume.

6.3.5 Treatment System Mass Removal

As stated, extracted groundwater is conveyed to the 200 West P&T, and it passes through IX resin for radiological treatment. Effluent from the resin is then combined with the influent groundwater from other extraction wells (that do not require radiological treatment) and is passed through the central treatment process. Effluent from the treatment system is then injected into the aquifer using the 200-ZP-1 injection wells. Section 4.1 (Chapter 4) provides a description of the treatment system and its performance during 2015. The uranium and technetium-99 removal efficiency for the entire system during 2016 averaged 97.9% and 96.3%, respectively (Chapter 2, Table 2-1).

6.4 Quality Assurance/Quality Control

Discussion on the QA/QC encompassing sampling and analysis of the 200-BP-5 OU wells is provided in Appendix E of DOE/RL-2016-67. The discussion includes an overall view of QA/QC issues that may affect interpretation of the groundwater data presented in this report.

6.5 Remedial System Costs

Remedial costs in 2016 were associated with final design and construction of the pipeline extension, which added well 299-E33-360 to the B Complex remedial system. Also added into the system expansion included two perched horizon wells, discussed in 200-DV-1 chapter. The actual cost breakdown for the final design and construction is provided in Table 6-4. The costs in Table 6-4 are burdened. The cross-site pipeline from well 299-E33-268 to the 200 West P&T was completed as part of the 200-BP-5 treatability test. As a result, design and construction costs in 2016 reflect extending the pipeline from well 299-E33-268 to well 299-E33-360.

Table 6-4. Cost Breakdown for 200-BP-5 OU Groundwater Extraction, 2016

Activity	Actual Costs ($)
Final design of pipeline extension	58,840
Construction of pipeline extension	931,980
Operations and maintenance *	734,040
Total	**1,724,860**

* The O&M cost is an apportionment of the overall 200 West P&T O&M cost based on percentage of mass treated from extracted BP-5 groundwater to the total mass treated by the 200 West P&T.

6.6 Conclusions

The following conclusions are made regarding the B Complex hydraulic conditions, source site releases, plume geometry, capture zone, and contaminant reduction based on observations associated with continued groundwater extraction at well 299-E33-268 in 2016:

- Groundwater level declines at the B Complex averaged approximately 1.6 to 2 mm/month.
- Removal of large volumes of groundwater over a short time (166 million L [43.8 million gal] over 12 months) from well 299-E33-268 had no discernable effect on the water table elevation in nearby monitoring wells.
- Extended periods of higher discharge at TEDF can decrease the groundwater gradient, causing slower flow rates.
- Groundwater contaminant concentrations appear to fluctuate in response to groundwater flow rates.
- Groundwater extraction from well 299-E33-268 had a significant effect (i.e., reduction) on the technetium-99 and uranium plume geometry and extent.
- Contaminant trending at wells to the north, south, east, and southeast indicate the capture zone from pumping at extraction well 299-E33-268 is in line with numerical model capture zone simulations.
- The combination of pumping at well 299-E33-268 and higher-than-normal discharges at TEDF appeared to prevent significant plume migration to the southeast of the B Complex.
- Groundwater extraction is an effective method for removing technetium-99 and uranium, as well as other co-contaminants.

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7 References

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*. Available at: https://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol22/xml/CFR-2010-title40-vol22-part141.xml.

ARH-CD-745, 1976, *Input and Decayed Values of Radioactive Liquid Wastes Discharged to the Ground in the 200 Areas Through 1975*, Atlantic Richfield Hanford Company, Richland, Washington. Available at: http://www.osti.gov/scitech/servlets/purl/5086808.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq., Pub. L. 107-377, December 31, 2002. Available at: http://epw.senate.gov/cercla.pdf.

CP-47631, 2011, *Model Package Report: Central Plateau Groundwater Model Version 3.3*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0075973H.

DOE-HDBK-1216-2015, 2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, DOE Handbook, U.S. Department of Energy, Washington, D.C. Available at: http://energy.gov/sites/prod/files/2015/03/f20/DOE-HDBK-1216-2015v2.pdf.

DOE/RL-96-61, 1997, *Hanford Site Background: Part 3, Groundwater Background*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D197226378.

DOE/RL-2001-41, 2015, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*, Rev. 8, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081640H.

DOE/RL-2008-02, 2008, *200-UP-1 and 200-ZP-1 Operable Units Pump and Treat System Annual Report for FY07*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0807230340.

DOE/RL-2008-78, 2009, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*, Rev. 0 REISSUE, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0096137.

DOE/RL-2009-38, 2009, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/pdf.cfm?accession=0095363.

DOE/RL-2009-115, 2014, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1411040775.

DOE/RL-2009-122, 2012, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0092344. http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0092342. http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0092341.

DOE/RL-2009-124, 2016, *200 West Pump and Treat Operations and Maintenance Plan*, Rev. 5, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0077130H.

DOE/RL-2010-13, 2010, *200 West Area Groundwater Pump-and-Treat Remedial Design Report*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084153.

DOE/RL-2010-74, 2015, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081243H.

DOE/RL-2011-102, 2016, *Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-DV-1 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0075538H.

DOE/RL-2011-118, 2012, *Hanford Site Groundwater Monitoring for 2011*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0091795.

DOE/RL-2012-03, 2012, *Calendar Year 2011 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1207180240.

DOE/RL-2012-36, 2012, *200 ZP-1 Interim Pump-and-Treat System Summary Performance Report for Calendar Year 2012*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1207180240.

DOE/RL-2013-07, 2013, *200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0087671.

DOE/RL-2013-14, 2013, *Calendar Year 2012 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0087669.

DOE/RL-2013-22, 2013, *Hanford Site Groundwater Monitoring Report for 2012*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0087974.

DOE/RL-2014-18, 2014, *Path Forward For Future 200-PW-1 Operable Unit Soil Vapor Extraction Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0082285H.

DOE/RL-2014-26, 2014, *Calendar Year 2013 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0083706.

DOE/RL-2014-34, 2014, *Action Memorandum for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0082284H.

DOE/RL-2014-37, 2015, *Removal Action Work Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080916H.

DOE/RL-2014-48, 2016, *Response Action Report for the 200-PW-1 Operable Unit Soil Vapor Extraction Remediation*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0074963H.

DOE/RL-2014-51, 2015, *Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080915H.

DOE/RL-2015-14, 2015, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080202H.

DOE/RL-2015-26, 2016, *Engineering Evaluation/Cost Analysis for the 200-BP-5 Operable Unit Groundwater Extraction*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0077225H.

DOE/RL-2015-75, 2016, *Aquifer Treatability Test Report for the 200-BP-5 Groundwater Operable Unit*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0077115H.

DOE/RL-2016-09, 2016, *Hanford Site Groundwater Monitoring Report for 2015*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0075314H.

DOE/RL-2016-20, 2016, *Calendar Year 2015 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0074339H.

DOE/RL-2016-41, 2016, *Action Memorandum for 200-BP-5 Operable Unit Groundwater Extraction*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0073242H.

DOE/RL-2016-66, 2017, *Hanford Site RCRA Groundwater Monitoring Report for 2016*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0077820H.

DOE/RL-2016-67, 2017, *Hanford Site Groundwater Monitoring Report for 2016*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-STD-1196-2011, 2011, *Derived Concentration Technical Standard*, U.S. Department of Energy, Washington, D.C. Available at: http://www.hss.doe.gov/nuclearsafety/techstds/docs/standard/DOE-STD-1196-2011.pdf.

ECF-200E-16-0093, 2016, *Preparation of 200 East Area Water Table Maps for Calendar Year 2015*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0072754H.

ECF-200W-17-0029, 2017, *Description of Groundwater Calculations and Assessments for the Calendar Year 2016 (CY 2016) 200 Areas Pump and Treat Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-200ZP1-13-0006, 2013, *Description of Groundwater Modeling Calculations for the Calendar Year 2012 (CY2012) 200 Areas Pump-and-Treat Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0078751H.

ECF-200ZP1-15-0002, *Description of Groundwater Modeling Calculations and Assessments of the River Protection Objective for the Calendar Year 2014 (CY2014) 200 Areas Pump-and-Treat Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-200ZP1-16-0076, 2016, *Description of Groundwater Calculations and Assessments for the Calendar Year 2015 (CY 2015) 200 Areas Pump and Treat Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0074966H.

ECF-HANFORD-16-0138, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2016 Hanford Site Groundwater Monitoring Report*, CH2M HILL Plateau Remediation Company, Richland, Washington.

Ecology, 2008, Cleanup Levels and Risk Calculations (CLARC) database, Washington State Department of Ecology, Olympia, Washington. Available at: https://fortress.wa.gov/ecy/clarc/.

Envirogen, 2017, *Evaluation Report of 200 West Pump & Treat Fluidized Bed Reactors*, Envirogen Technologies, Kingwood, Texas. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0069779H.

Environmental Dashboard Application, 2017, U.S. Department of Energy. Available at: https://ehs.hanford.gov/eda/.

EPA 816-F-00-002, 2002, *Implementation Guidance for Radionuclides*, Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency, Washington, D.C. Available at: https://www.epa.gov/sites/production/files/2015-09/documents/2009_04_16_radionuclides_guide_radionuclides_stateimplementation.pdf.

EPA, 1995, *Record of Decision, U.S. DOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, U.S. Department of Energy, and Washington State Department of Ecology. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196041064.

EPA, Ecology, and DOE, 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=00098825.

EPA, Ecology, and DOE, 2011, *Record of Decision Hanford 200 Area Superfund Site 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093644.

EPA, Ecology, and DOE, 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0091413.

EPA/ESD/R10-96/145, 1996, *Explanation of Significant Differences: USDOE Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093773.

EPA/ROD/R10-95/114, 1995, *EPA Superfund Record of Decision: Hanford 200-Area (USDOE) OU 200-ZP-1, Benton County, WA 5/24/95*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=9100NWA2.txt.

HNF-EP-0182, 2016, *Waste Tank Summary Report for Month Ending December 31, 2015*, Rev. 336, Washington River Protection Solutions, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1602250271.

One Water Solutions, 2016, *Effluent Technical Review Services Contract No. 60073*, One Water Solutions, Ann Arbor, Michigan. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0069782H

PNNL-11810, 1998, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D198175192.

PNNL-12261, 2000, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0906180659.

PNNL-19277, 2010, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084238.

PNNL-19702, 2010, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/publications/abstracts.asp?report=299890.

PNNL-21843, 2013, *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0088374.

PNNL-26341, 2017, *Letter Report: Stable Hydrogen and Oxygen Isotope Analysis of B-Complex Perched Water Samples*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26341.pdf.

PNNL-26404, 2017, *200 West Pump-and-Treat Facility Biofouling Assessment, Pacific Northwest National Laboratory*, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. Available at: https://elr.info/sites/default/files/docs/statutes/full/rcra.pdf.

RPP-26744, 2005, *Hanford Soil Inventory Model, Rev. 1*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081114H.

SGW-42305, 2009, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0911170654.

SGW-50907, 2011, *Predicted Impact of Future Water-Level Declines on Groundwater Well Longevity within the 200 West Area, Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0078753H.

SGW-53604, 2012, *Path Forward Recommendations Report for the Uranium Contamination in the B Area*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0088372.

SGW-53604, 2013, *Path Forward Recommendations Report for the Uranium Contamination in the B Area*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0086487.

SGW-54165, 2014, *Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site*, Rev. 0. CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0085682.

SGW-58147, 2015, *Annual Performance Report for the 200-DV-1 Operable Unit Perched Water Extraction, Fiscal Year 2014*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081530h.

SGW-58828, 2015, *Water Table Maps for the Hanford Site 200 East Area, 2013 and 2014*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079727H.

SGW-59086, 2015, *Annual Performance Report for the 200-DV-1 Operable Unit Perched Water Extraction, Fiscal Year 2015*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0078757H.

SGW-60655, 2017, *Surface Infiltration Evaluation Report for the 200 West Pump and Treat Facility*, pending, CH2M HILL Plateau Remediation Company, Richland, Washington.

Smith, R.F. and R. Stanley, 1992, "Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume" (letter to R.D. Izatt, U.S. Department of Energy, Richland Operations Office), U.S. Environmental Protection Agency, Region 10, and Washington State Department of Ecology, January 21. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196088487.

SRNL-STI-2017-0163, 2017, *Evaluation of the Hanford 200 West Groundwater Treatment System: Fluidized Bed Bioreactor*, Rev. 0, Savannah River National Laboratory, Aiken, South Carolina. Available at: http://sti.srs.gov/fulltext/SRNL-STI-2017-0163.pdf.

Tonkin, M.J., J. Kennel, W. Huber, and J. Lambie, 2013, *A Hybrid Analytic Element Universal Kriging Interpolation Technique Built in the Open Source R Environment*, American Geophysical Union Fall Meeting, San Francisco, California.

WAC 173-340, "Model Toxics Control Act—Cleanup," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340.

340-705, "Use of Method B."

340-720, "Groundwater Cleanup Standards."

WAC 246-290, "Group A Public Water Supplies," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=246-290.

WHC-EP-0133, 1988, *U1/U2 Uranium Plume Characterization, Remedial Action Review and Recommendation for Future Action*, Westinghouse Hanford Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196044962.

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Appendix A

Perched-Water Aquifer Hydraulic Test Analysis

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A1 Perched-Water Aquifer Hydraulic Test Analysis

Hydraulic testing for the 200- DV-1 Operable Unit perched water conducted in 2016 during startup extraction operations using all three extraction wells was designed and analyzed by Pacific Northwest National Laboratory. The test report prepared by Pacific Northwest National Laboratory to provide the results and interpretation is provided as supporting information in this appendix.

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Perched-Water Aquifer Hydraulic Test Analysis

Frank Spane, Darrell Newcomer, and Mike Truex

November, 2016

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1 Summary

The contaminated-water recovery system for the perched-water aquifer (PWA) present in the Hanford 200 East Area B-Complex was recently updated by installing two new wells (299-E33-350 and 299-E33-351) to augment the existing recovery well 299-E33-344. The update also included instrumentation of all three extraction wells with pressure and flow sensors suitable for conducting hydraulic testing. Hydraulic testing was conducted during start-up of the new three-well system in FY16, as identified in the CHPRC procedure for the perched water well expansion operational acceptance test and startup.

Three tests were conducted, as outlined in the procedure. Test 1, Baseline Monitoring, was conducted with the objective of establishing barometric response functions for perched-water extraction wells to minimize barometric pressure effects in the water-level data and provide insight into the vadose zone overlying the PWA. This activity was necessary to enable processing of the pressure data for use in analyzing data for Tests 2 and 3. Test 2, Single-Well Pump Testing, was conducted with the objective of determining near- and inter-well hydrologic properties for the PWA. Test 3, Multi-Well Pump Testing, was conducted with the objective of assessing the PWA extent through analysis of any observed hydrologic boundary detection and/or aquifer dewatering during the test.

Barometric response functions generated using Test 1 data accounted for about 80% of the well data barometric dependence. While these functions enabled analysis of Test 2 and Test 3 data, additional baseline (quiescent) monitoring could be used to improve the barometric response functions and facilitate better interpretation of hydraulic head data. During the baseline monitoring period, the data show a gradient in the PWA toward the south east (azimuth of 114 degrees) that may be all or partially a remnant hydraulic response from historical pumping at well 299-E33-344. The baseline data also show a trend of increasing water level of about 1.09e-3 m/day in well 299-E33-344 and about 1.07e-4 m/day 299-E33-351.

The Test 2 data at each well were evaluated using a single-well (pumped-well) analysis to estimate hydraulic properties. Table S1 summarizes these results. Analysis of Test 2 monitoring location results was difficult because of the low signal to noise ratio of the data. With additional data to improve the barometric response functions, these Tests 2 data could be re-evaluated to estimate hydraulic properties based on observation-well data rather than only on the pumping-well data.

Table S1. Estimated PWA hydraulic properties.

Well	T m^2/day	K_h m/day	S	S_y	β_w	K_v/K_h
299-E33-344	0.51	0.13	1.33e-3	0.151	5.5e-5	0.03
299-E33-350	4.01	1.05	4.5e-3	0.273	3.2e-5	0.02
299-E33-351	3.50	0.91	9.0e-4	0.220	1.5e-5	0.01

Transmissivity: $T = K_h\, b$ (note: b [aquifer saturated thickness] assumed to be 3.81 m for all analyses)

Horizontal Hydraulic Conductivity: K_h Vertical Hydraulic Conductivity: K_v Well radius: r_w

Storativity: S Specific Yield: S_y Beta: $\beta_w = (r_w/b)^2 (K_v/K_h)$ Vertical Anisotropy: K_v/K_h

While the Test 3 pumping rate was lower than initial plans due to the logistics of aboveground treatment and the failure of the pump in well 299-E33-351, the pumped volume should have been sufficient to cause a measurable dewatering response if the aquifer areal extent were equal to (or less than) about 33,500 m^2 and there were no continuing net influx of water to the PWA. Barometric-corrected water-level data at well 299-E33-351 (Figure S1), which acted as an observation well for Test 3 because its pump failed early in the test, shows rapid and complete recovery of the water level to pre-test conditions, consistent with the overall increasing water-level trend observed in Test 1. The pumping and recovery data for well 299-E33-351 do not show any characteristics of a hydrologic boundary (i.e., the edge of the PWA). The data also do not indicate any dewatering response. These results are interpreted as meaning 1) the PWA is larger in extent than currently conceptualized or 2) the effects of pumping (e.g., dewatering, hydraulic recovery) are being affected by the recharge/discharge balance (water balance of influx and outflux) for the PWA.

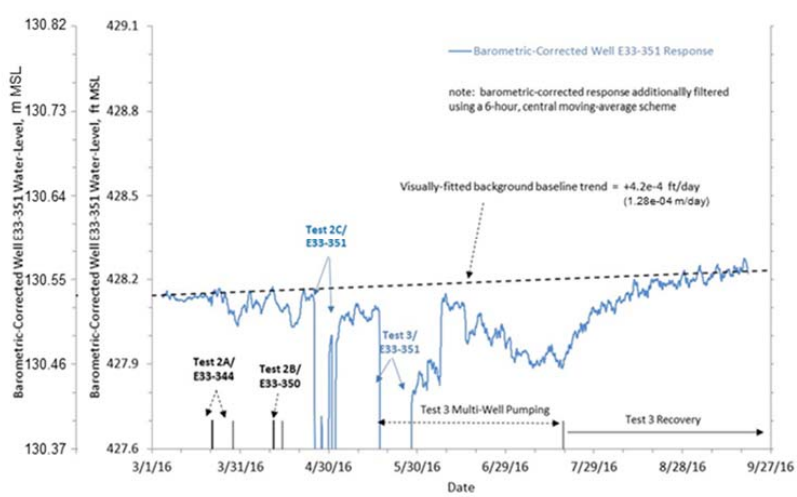

Figure S1. Test 3 water-level data for well 299-E33-351

The hydraulic testing results were evaluated to develop several recommendations with respect to future PWA recovery operations. First, it is recommended that the Test 3 recovery period monitoring be extended through the end of October 2016 (i.e., while the new aboveground system and treatment approach is being finalized) to provide a longer baseline (quiescent) data set than was obtained in Test 1. This enhanced baseline data set can be used to reduce well pressure noise and facilitate analysis of FY16

data and of new performance assessment data collected in FY17 and over the duration of the recovery operations. Second, it is recommended that well 299-E33-344 be used as an observation well initially when operational pumping is started in FY17. It is anticipated that the longer-term FY17 operational pumping with wells 299-E33-350 and -351 will eventually produce enough stress on the PWA to enable estimating the PWA size and/or to help resolve the water balance of influx versus outflux. The types of recommended data evaluation 1) during operational pumping, 2) for a recovery period after an extended period of pumping (6+ months), and 3) to evaluate the PWA water balance are conceptually shown in Figures S2, S3, and S4, respectively. Because well 299-E33-344 yields much lower extraction flow rates than are obtained in wells 299-E33-350 and -351, overall recovery of contaminated PWA water is minimally affected with use of well 299-E33-344 as a monitoring well, and important performance monitoring data can be obtained. After this initial operational period with well 299-E33-344 pump turned off and when sufficient data have been collected, the well can be turned on for use as a recovery well.

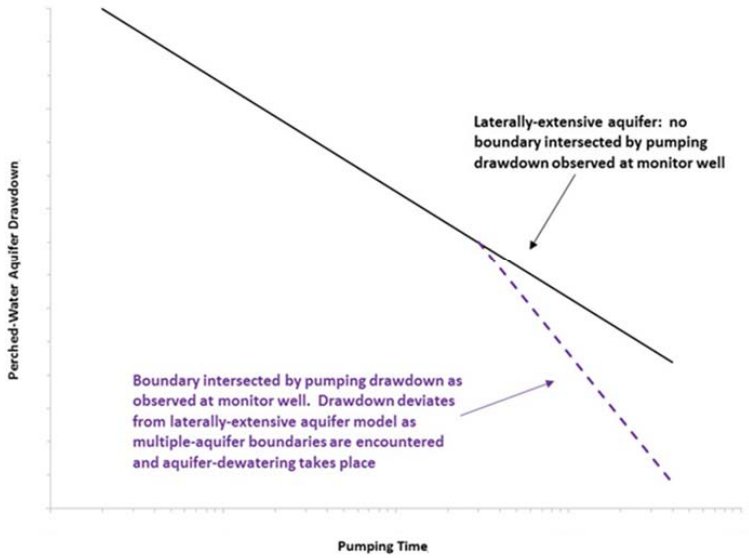

Figure S2. Conceptual response for a monitoring well (e.g., 299-E33-344) during pumping with and without contacting a hydraulic boundary.

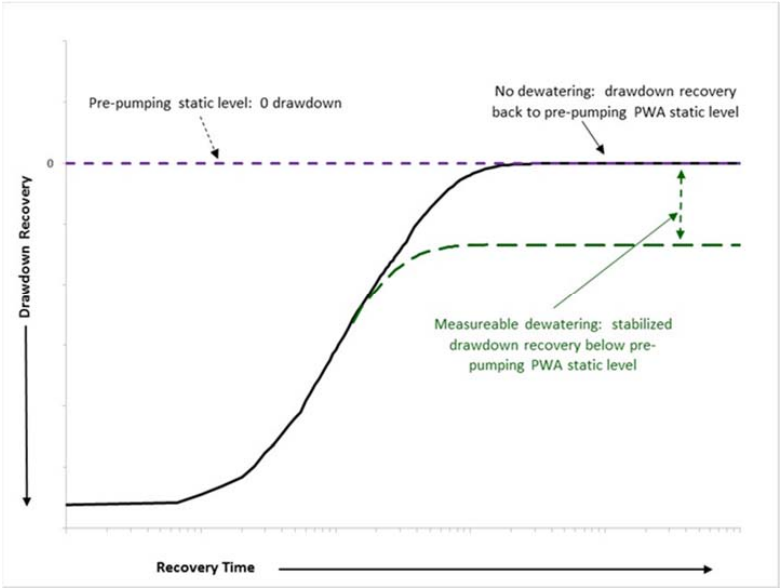

Figure S3. Conceptual recovery response after extended pumping to measure a dewatering response that can be used to estimate PWA extent.

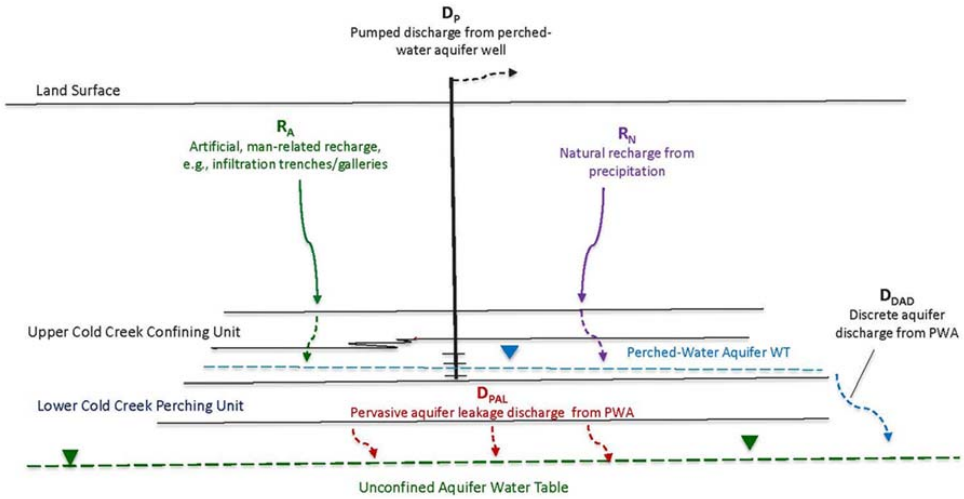

Figure S4. Conceptual depiction of the dynamic PWA water balance system.

Water budgets along with hydraulic data could be used to better identify the influx-outflux balance in the system that is related to the dewatering ability of the pumping-well system.

2 Introduction

A contaminated perched-water aquifer (PWA) is present in the Hanford 200 East Area B-Complex, as described in characterization (Serne et al. 2010; SGW-53604), analysis (Truex et al. 2013; Oostrom et al. 2013; Newcomer 2014), and perched-water recovery operational documents (SGW-59086). Recovery of the contaminated perched water was initiated in 2011 using well 299-E33-344. The water extraction rate is slow due to the low permeability and thin saturated interval of the aquifer. The contaminated-water recovery system for the PWA was recently updated by installing two new wells (299-E33-350 and 299-E33-351) to augment the existing recovery well 299-E33-344. The update also included instrumentation of all three extraction wells with pressure and flow sensors suitable for conducting hydraulic testing. Hydraulic testing was conducted during start-up of the new three-well system in FY16, as identified in the CHPRC procedure for the perched water well expansion operational acceptance test and startup.

Three tests were conducted as outlined in the procedure. Test 1, Baseline Monitoring, was conducted to collect data under quiescent conditions. Test 2, Single-Well Pump Testing, included sequential pump tests at each of the PWA extraction wells. Test 3, Multi-Well Pump Testing, was conducted with extraction from multiple wells over a long duration for analysis as a large-scale pumping test.

3 Objectives

Test 1, Baseline Monitoring, was conducted with the objective of establishing barometric response functions for perched-water extraction wells to minimize barometric pressure effects in the water-level data and provide insight into the vadose zone overlying the PWA. This activity was necessary to enable processing of the pressure data for use in analyzing data for Tests 2 and 3. Test 2, Single-Well Pump Testing, was conducted with the objective of determining near- and inter-well hydrologic properties for the PWA. Test 3, Multi-Well Pump Testing, was conducted with the objective of assessing the PWA extent through analysis of any observed hydrologic boundary detection and/or aquifer dewatering during the test.

4 Testing Approach

The hydraulic testing approach consisted of three types of tests.

Test 1: Functional Testing and Baseline Water Level Data

Each well was cycled on to verify all operational aspects of the pumping and data collection system and to evaluate the sustainable pumping rate/cycle. Once these tests were complete, the perched water system remained off for 30 days and water level and barometric data was collected under quiescent conditions. Table 1 shows the test schedule. Data analyses were conducted using the methods of Mackley et al. (2010), Rasmussen and Crawford (1997), Spane (1999, 2002), and Spane and Mackley (2011).

Table 1. Test 1 Elements

Dates	Element
2/16/16 – 2/18/16	Conducted and documented pumping and data system function.
2/20/2016 – 3/21/16	Baseline water level and barometric data were collected.

Test 2: Individual Pumping Well Hydraulic Testing

Independent pumping and recovery tests were conducted sequentially at each well to define aquifer properties adjacent to each well. Pumping durations were estimated to provide sufficient stress to the perched aquifer to enable analysis of hydraulic properties. Associated recovery times based on this stress were also estimated so that the aquifer would recover from one test prior to starting another test. Table 2 shows the test schedule. Data analyses were conducted using the methods of Duffield (2007) and Spane and Newcomer (2009).

Table 2. Test 2 Elements

Dates	Element
3/21/16 – 3/28/16	Continuous pumping cycles from Well -344 with monitoring.
3/28/2016 – 4/11/16	Monitored water table recovery under quiescent conditions.
4/11/16 – 4/14/16	Continuous pumping cycles from Well -350 with monitoring. Abbreviated cyclical pumping period due to operational pump/well pressure setting constraints.
4/14/16 – 4/25/16	Monitored water table recovery under quiescent conditions.
4/25/16 – 5/2/16	Continuous pumping cycles from Well -351 with monitoring.
5/2/16 – 5/17/16	Monitored water table recovery under quiescent conditions.

Test 3: Composite Pumping Hydraulic Testing

A composite pumping and recovery test was conducted with all three pumps operating long enough for the pumping stress to the aquifer to propagate a long distance from the pumping wells. In this way, analysis of the pumping data and the associated water level recovery can be applied to estimate the aquifer dimensions and larger-scale aquifer dynamics. This information enhances the ability to evaluate the performance of the perched water extraction system in the context of aquifer desaturation and reducing contaminant flux to groundwater. Table 3 shows the test schedule.

Table 3. Test 3 Elements

Dates	Element
5/17/16 – 7/18/16	Continuous pumping cycles from all three wells with monitoring. However, pumping at well 299-E33-351 was terminated due to a pump malfunction on 5/26/16 and this pump remained off for the duration of the testing, acting as a monitoring well.
7/18/2016 – 9/16/16	Monitored water table recovery under quiescent conditions.

5 Testing Results

The three hydraulic test results are described in the following sections.

5.1 Test 1 Results

During Test 1, Baseline Monitoring, collected barometric and water-level data fluctuate inversely over a range of about 0.37 m (e.g., Figure 1). The cause of the fluctuation is the imbalance in pressure measured within the well (with a vented pressure probe) and the pressure within the surrounding PWA. Each well showed a similar response indicating a similarity in barometric transmission characteristics for the area represented by these wells. Spectral analysis of the data indicate that the water-level response was highly associated with the barometric pressure signal over the entire frequency spectrum. While not conducted as part of this effort, the in situ vertical hydraulic diffusivity (and ultimately the vertical hydraulic conductivity) for the upper and lower CCUz layers of the PWA could be estimated using this type of spectral data.

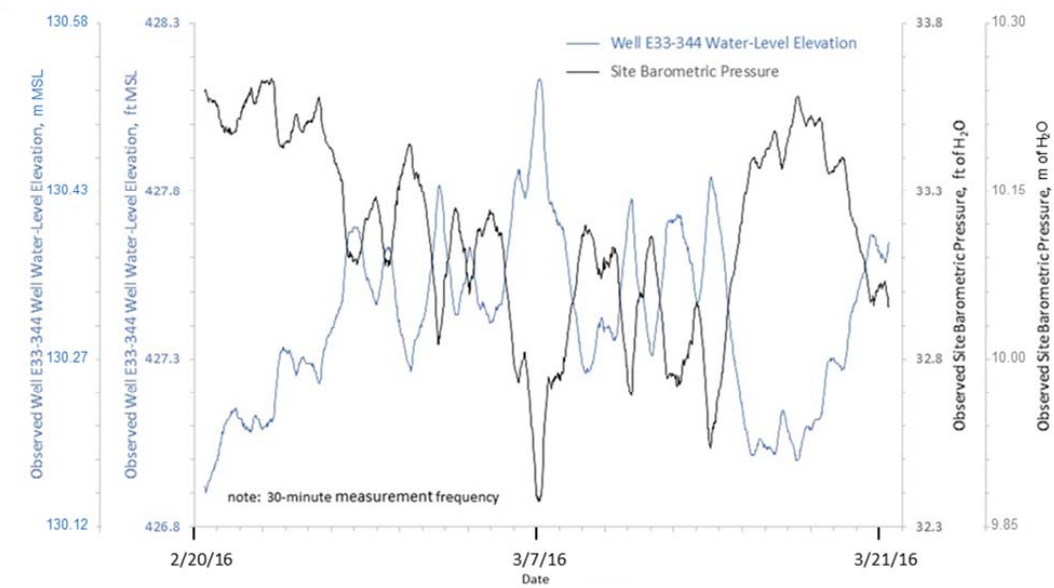

Figure 1. Baseline water-level and barometric data for well 299-E33-344.

Barometric response functions (functions that enable removing barometric fluctuations from water-level data) generated using Test 1 data accounted for about 80% of the well data barometric dependence. The barometric response functions for each well exhibit complex time-lag patterns, likely caused by multiple barometric transmission pathways/conditions from the surface to the PWA. For wells 299-E33-350 and -

351, the early-time (0-80 hr of time lag) shows a vertical pressure transmission pattern. The subsequent prolonged constant barometric response function pattern suggests the presence of surrounding confined aquifer conditions for the PWA (Figure 2). In contrast, well 299-E33-344 shows a delayed pattern in the first 8 hours indicative of wellbore storage effects and likely lower transmissivity conditions surrounding the well. This initial response is followed by multiple zones of response patterns (Figure 3). While the developed barometric response functions enabled analysis of Test 2 and Test 3 data, additional baseline (quiescent) monitoring could be used to improve the barometric response functions and facilitate better interpretation of hydraulic head data.

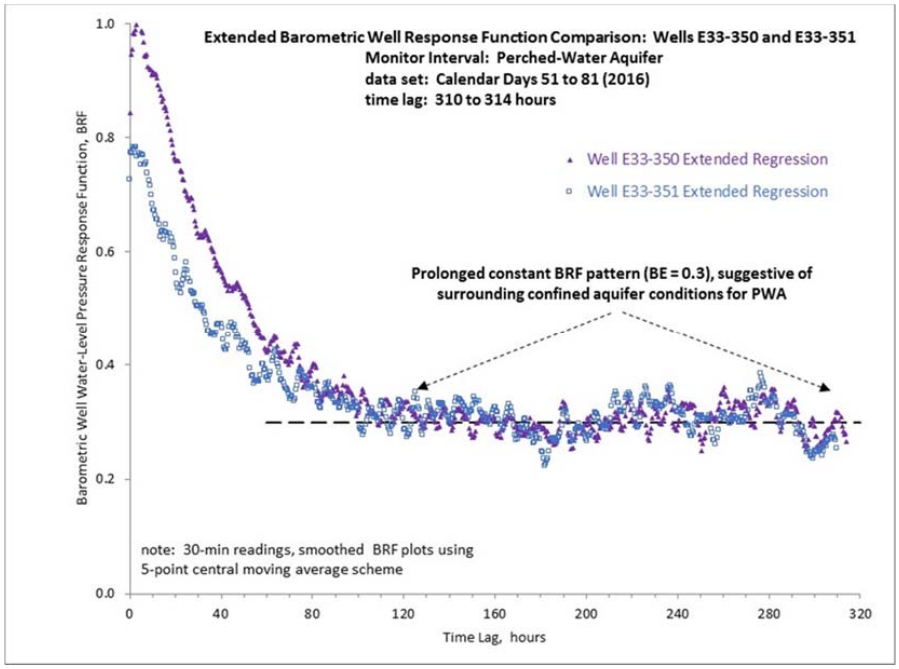

Figure 2. Barometric response function analysis for wells 299-E33-350 and -351.

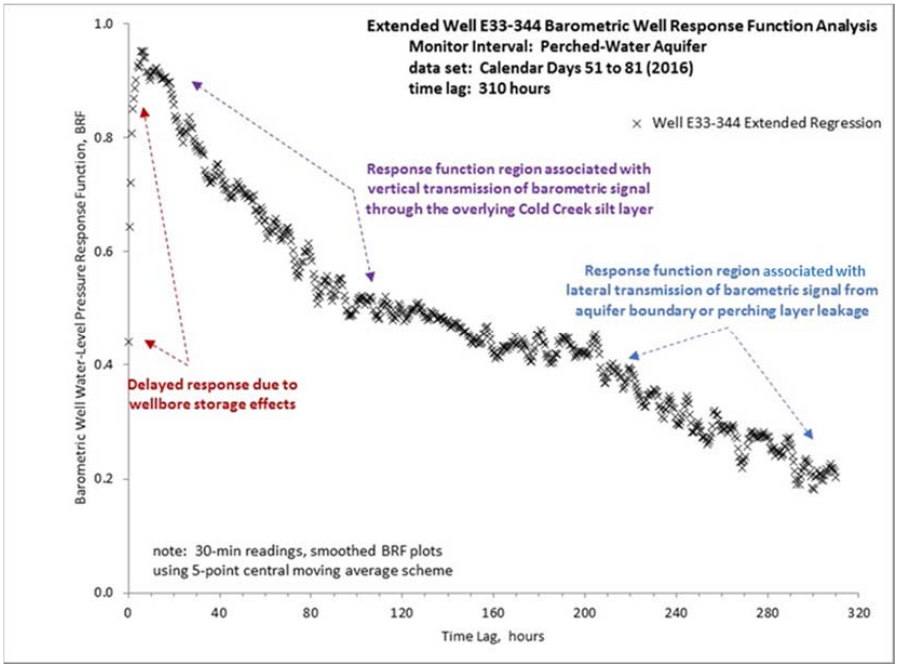

Figure 3. Barometric response function analysis for wells 299-E33-344.

During the baseline monitoring period, the data show a gradient in the PWA toward the south east (azimuth of 114 degrees) that may be all or partially a remnant hydraulic response from historical pumping at well 299-E33-344 (Figure 4). The baseline data also show a trend of increasing water level of about 1.09e-3 m/day in well 299-E33-344 and about 1.07e-4 m/day 299-E33-351 (Figure 5).

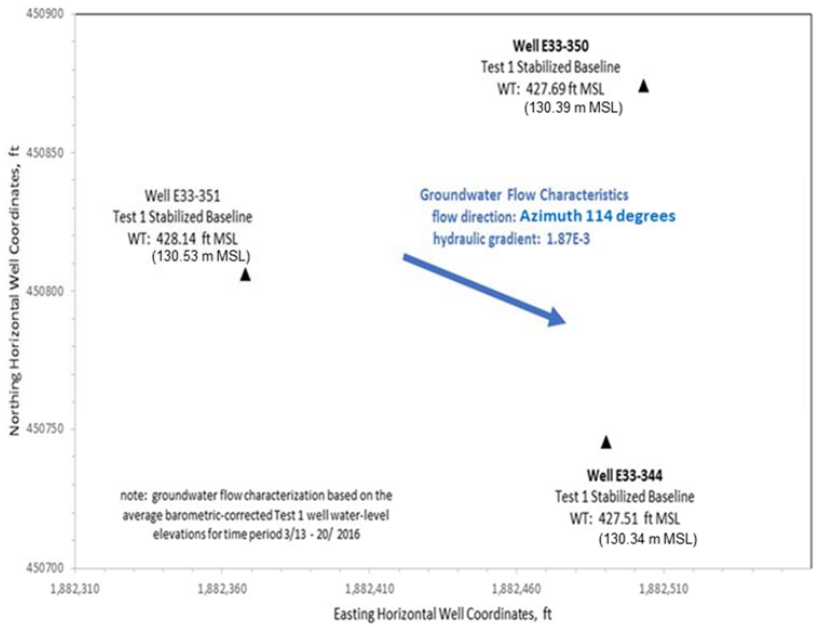

Figure 4. Estimated hydraulic gradient from data collected during Test 1.

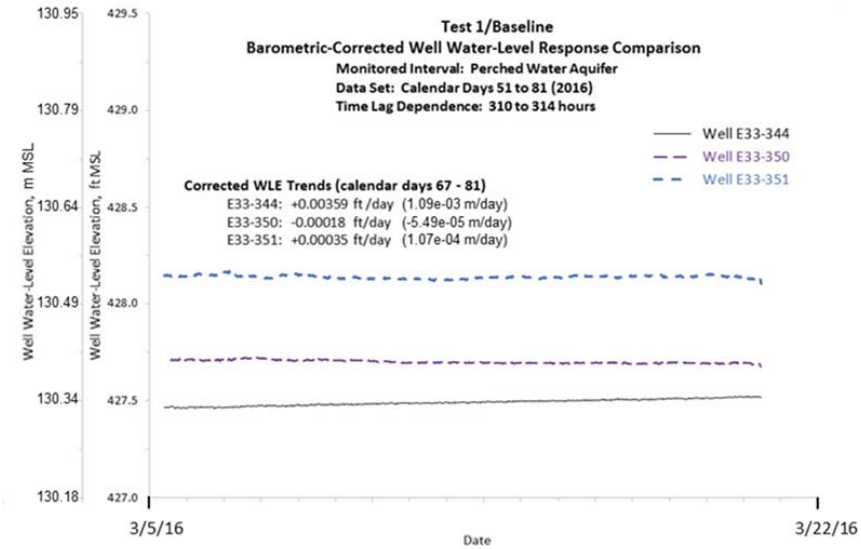

Figure 5. Subset of corrected water-level data for the three tested wells.

5.2 Test 2 Results

Test 2 included single-well pumping sequentially at each of the wells. Note that these pumping rates were adjusted to meet aboveground water-handling constraints, so do not necessarily reflect maximum pumping rates for these wells. At well 299-E33-344, there were 299 uninterrupted pumping cycles over 7 days of testing. 6188 L (1635 gallons) were extracted at an average flow rate of 0.61 L/m (0.162 gpm, average cycle time was 1.3 minutes on and 32.6 minutes off with an average in-cycle pumping rate of 16.3 L/m [4.3 gpm]). At well 299-E33-350, there were 113 uninterrupted pumping cycles over 3.5 days of testing. 5768 L (1524 gallons) were extracted at an average flow rate of 1.14 L/m (0.302 gpm, average cycle time was 5.7 minutes on and 39.3 minutes off with an average in-cycle pumping rate of 9.1 L/m [2.4 gpm]). At well 299-E33-351, there were 496 uninterrupted pumping cycles over 7 days of testing. 9762 L (2579 gallons) were extracted at an average flow rate of 0.97 L/m (0.256 gpm, average cycle time was 2.5 minutes on and 17.8 minutes off with an average in-cycle pumping rate of 9.8 L/m [2.6 gpm]). The Test 2 data at each well were evaluated using a single-well (pumped-well) analysis to estimate hydraulic properties. Table 4 summarizes the results. Analysis of Test 2 monitoring location results was difficult because of the low signal to noise ratio of the data. With additional data to improve the barometric response functions, these Test-2 data could be re-evaluated to estimate hydraulic properties based on observation well data rather than only on the pumping-well data.

Table 4. Estimated PWA hydraulic properties.

Well	T m^2/day	K_h m/day	S	S_y	β_w	K_v/K_h
299-E33-344	0.51	0.13	1.33e-3	0.151	5.5e-5	0.03
299-E33-350	4.01	1.05	4.5e-3	0.273	3.2e-5	0.02
299-E33-351	3.50	0.91	9.0e-4	0.220	1.5e-5	0.01

Transmissivity: $T = K_h b$ (note: b [aquifer saturated thickness] assumed to be 3.81 m for all analyses)
Horizontal Hydraulic Conductivity: K_h Vertical Hydraulic Conductivity: K_v Well radius: r_w
Storativity: S Specific Yield: S_y Beta: $\beta_w = (r_w/b)^2 (K_v/K_h)$ Vertical Anisotropy: K_v/K_h

5.3 Test 3 Results

During Test 3, 56,790 L (15,004 gallons) were extracted from well 299-E33-344, 126,726 L (33,481 gallons) were extracted from well 299-E33-350, and 24,455 L (6,461 gallons) were extracted from well 299-E33-351 (this well was only pumped for about 10 days). Note that these pumping rates were adjusted to meet aboveground water-handling constraints, so do not necessarily reflect maximum pumping rates for these wells. While the Test 3 pumping rate was lower than initial plans due to the logistics of aboveground treatment and the failure of the pump in well 299-E33-351, the pumped volume should have been sufficient to cause a measurable dewatering response if the aquifer areal extent were equal to (or less than) about 33,500 m^2 (see Figure 6) and there were no continuing net influx of water to the PWA. The calculated, uniformly-distributed, dewatering/desaturation across the PWA for the three specific yield (Sy) conditions shown below are greater than the ~0.9 cm quantitative detection limit for barometric-corrected well pressure response. Thus, it was expected that a measurable dewatering would have been observed for Test 3.

- Sy = 0.15; Aquifer Dewatering = 4.4 cm
- Sy = 0.25; Aquifer Dewatering = 2.7 cm
- Sy = 0.35; Aquifer Dewatering = 1.9 cm

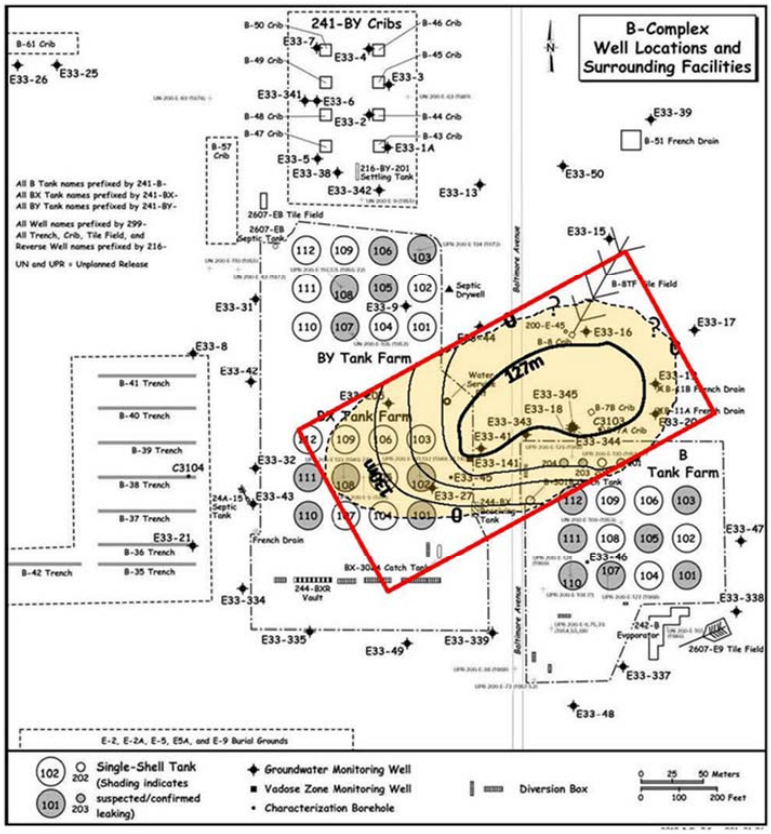

Figure 6. Generalized configuration of the Perched-Water Aquifer to estimate the areal extent (after SGW-53604).

Barometric-corrected water-level data at well 299-E33-351 (Figure 7), which acted as an observation well for Test 3 because its pump failed early in the test, shows rapid and complete recovery of the water level to pre-test conditions, consistent with the overall increasing water-level trend observed in Test 1. The pumping and recovery data for well 299-E33-351 do not show any characteristics of a hydrologic boundary (i.e., the edge of the PWA). The data also do not indicate any dewatering response. The wells that were pumped for the full duration of Test 3 also appear to show similar recovery characteristics. Barometric-corrected water-level data at well 299-E33-350 (Figure 8) also show rapid recovery of the water level, trending toward a complete recovery (actually reaching complete recovery if the Test-1 baseline trend of declining water level at this location is considered). Barometric-corrected water-level data at well 299-E33-344 (Figure 9) show recovery of the water level slowly approaching pre-test conditions. The recovery for this well is expected to be slower because of the low PWA transmissivity surrounding this well (Table 4). Additional recovery data for this well would be useful in confirming whether full recovery will be achieved. These composite well-recovery results are interpreted as meaning 1) the PWA is larger in extent than currently conceptualized or 2) the effects of pumping (e.g., dewatering, hydraulic recovery) are being affected by the recharge/discharge balance (water balance of influx and outflux) for the PWA.

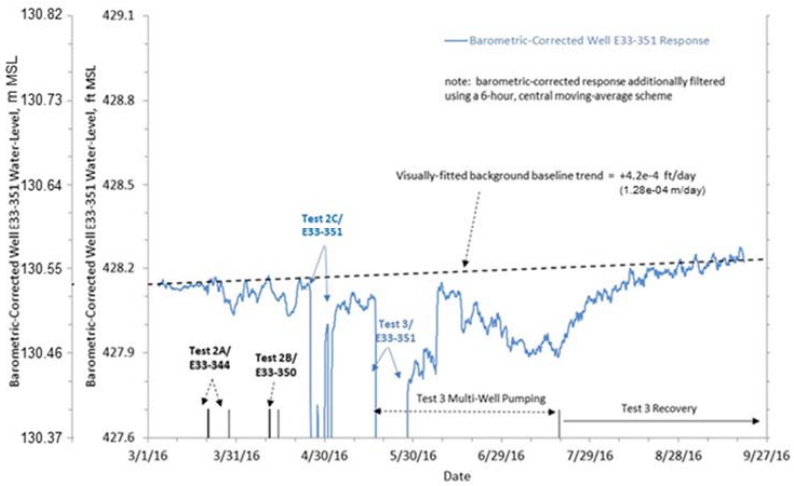

Figure 7. Test 3 water-level data for well 299-E33-351.

The visually fitted background water-level trend of 1.28e-4 m/day is similar to the Test-1 trend for this well of 1.07e-4 m/day.

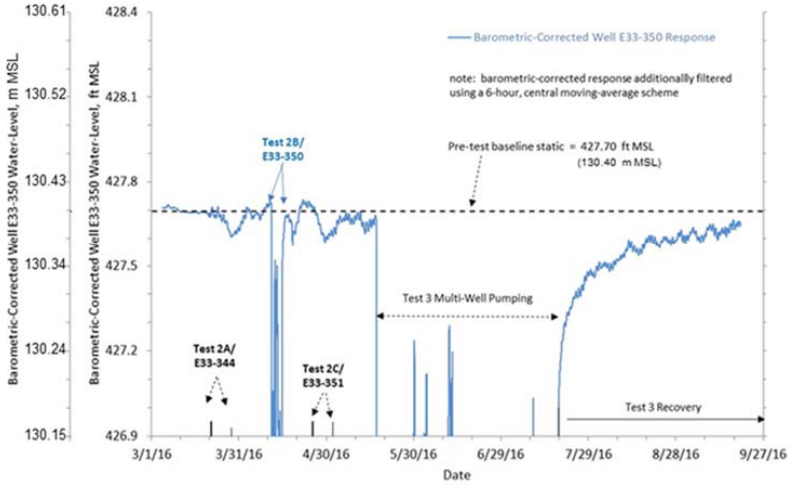

Figure 8. Test 3 water-level data for well 299-E33-350.

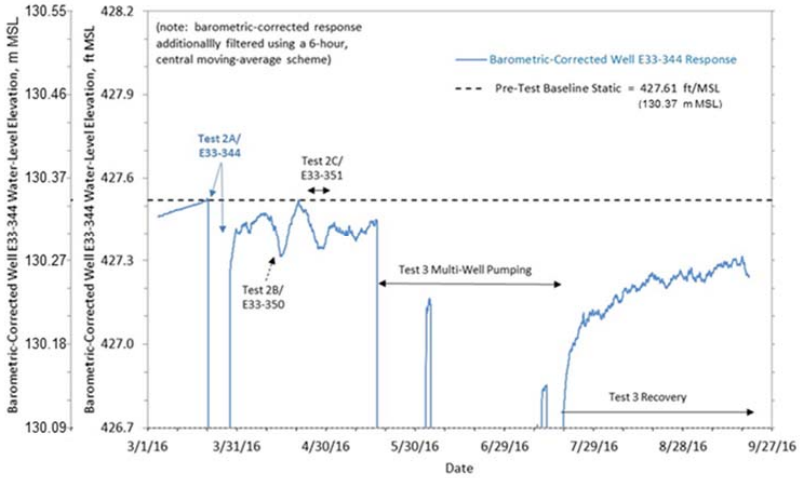

Figure 9. Test 3 water-level data for well 299-E33-344.

6 Recommendations

The hydraulic testing results were evaluated to develop several recommendations with respect to future PWA recovery operations. First, it is recommended that the Test 3 recovery period monitoring be extended through the end of October 2016 (i.e., while the new aboveground system and treatment approach is being finalized) to provide a longer baseline (quiescent) data set than was obtained in Test 1 (Figure 10). This enhanced baseline data set can be used to reduce well pressure noise and facilitate analysis of FY16 data and of new performance assessment data collected in FY17 and over the duration of the recovery operations. Second, it is recommended that well 299-E33-344 is used as an observation well initially when operational pumping is started in FY17. It is anticipated that the longer-term FY17 operational pumping with wells 299-E33-350 and -351 will eventually produce enough stress on the PWA to enable estimating the PWA size and/or to help resolve the water balance of influx versus outflux. The types of recommended data evaluation 1) during operational pumping, 2) for a recovery period after an extended period of pumping (6+ months), and 3) to evaluate the PWA water balance are conceptually shown in Figures 11, 12, and 13, respectively. Because well 299-E33-344 yields much lower extraction flow rates than are obtained in wells 299-E33-350 and -351, overall recovery of contaminated PWA water is minimally affected with use of well 299-E33-344 as a monitoring well, and important performance monitoring data can be obtained. After this initial operational period with well 299-E33-344 pump turned off and when sufficient data have been collected, the well can be turned on for use as a recovery well.

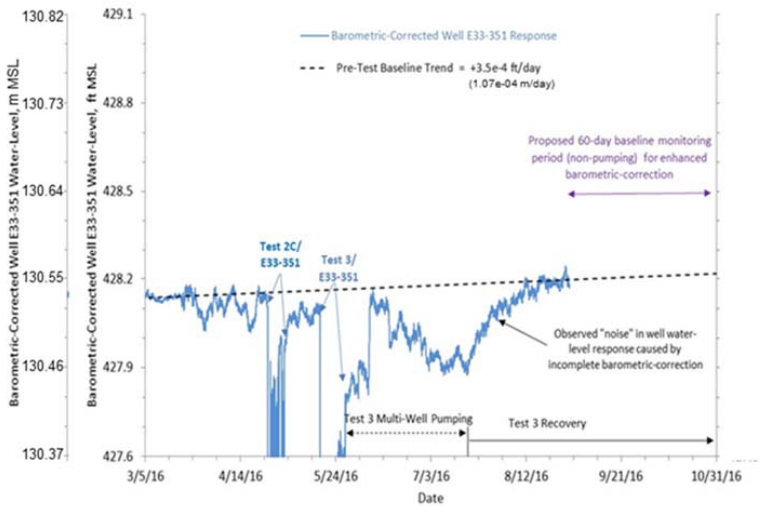

Figure 10. Depiction of extended Test 3 recovery period monitoring.

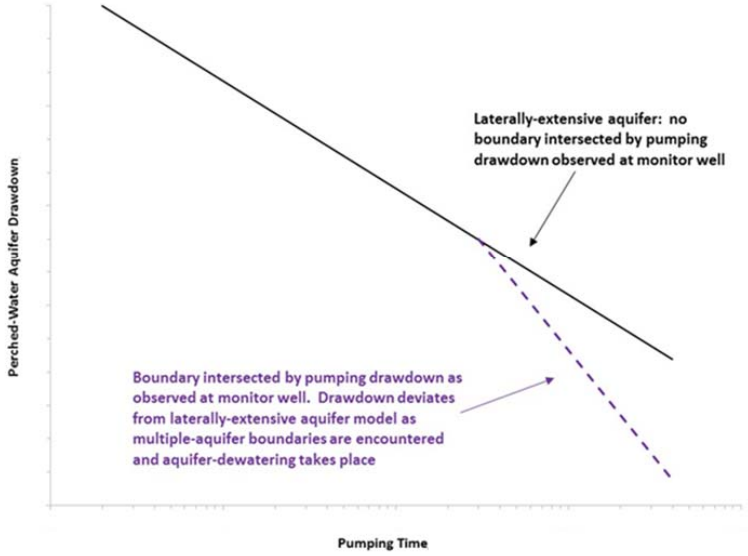

Figure 11. Conceptual response for a monitoring well (e.g., 299-E33-344) during pumping with and without contacting a hydraulic boundary.

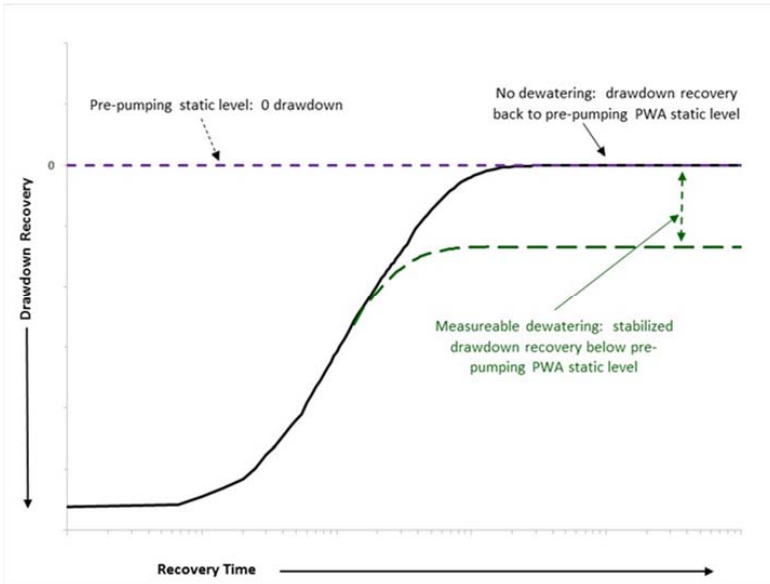

Figure 12. Conceptual recovery response after extended pumping to measure a dewatering response that can be used to estimate PWA extent.

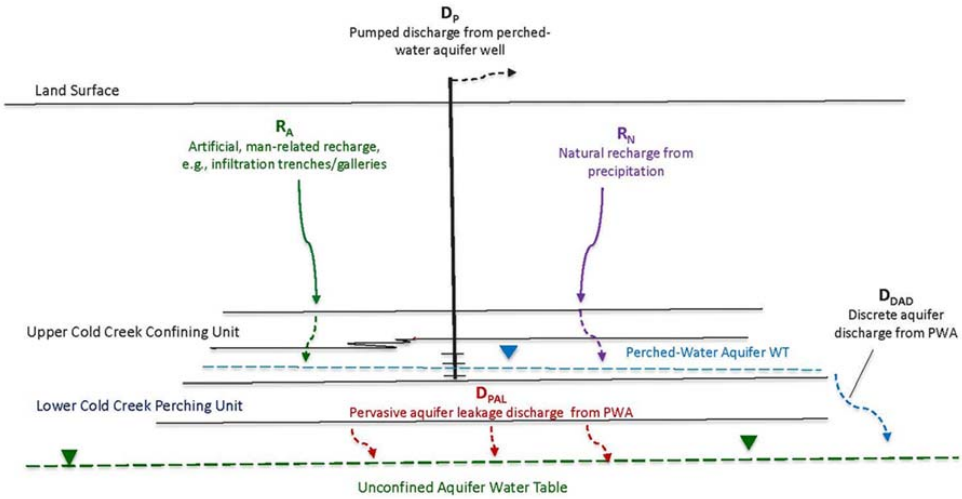

Figure 13. Conceptual depiction of the dynamic PWA water balance system.

Water budgets along with hydraulic data could be used to better identify the influx-outflux balance in the system that is related to the dewatering ability of the pumping-well system.

References

Duffield, GM. 2007. "AQUESOLV for Windows Version 4.5 User's Guide." HydroSOLVE, Inc., Reston, Virginia (http://www.aqtesolv.com).

Mackley, R D, FA Spane, TC Pulsipher, and CH Allwardt. (September) 2010. "Guide to using Multiple Regression in Excel (MRCX v.1.1) for Removal of River-Stage Effects from Well Water Levels." PNNL-19482, Pacific Northwest National Laboratory, Richland, Washington.

Newcomer, DR. 2014. "Field-Derived Hydraulic Properties for Perched-Water Aquifer Wells 299-E33-350 and 299-E33-351, Hanford Site B-Complex Area." PNNL-23380, Pacific Northwest National Laboratory, Richland, WA.

Oostrom, M. M.J. Truex, K.C. Carroll, and G.B. Chronister. 2013. "Perched-water Analysis Related to Deep Vadose Zone Contaminant Transport and Impact to Groundwater." *J. Hydrology.* 505: 228–239. doi:/10.1016/j.jhydrol.2013.10.001.

Rasmussen TC and LA Crawford. 1997. "Identifying and Removing Barometric Pressure Effects in Confined and Unconfined Aquifers." *Ground Water* 35(3):502-511.

Serne R, B Bjornstad, J Keller, P Thorne, D Lanigan, J Christensen, and G Thomas. 2010. "Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Upper Unconfined Aquifer Below the B-Complex." PNNL-19277, Pacific Northwest National Laboratory, Richland, Washington.

SGW-53604, Rev. 1. 2013. "Path Forward Recommendations Report for the Uranium Contamination in the B Area." prepared for U.S. Department of Energy by CH2M, Richland, WA.

SGW-59086, Rev. 0. 2015. "Annual Performance Report for the 200-DV-1 Operable Unit Perched Water Extraction, Fiscal Year 2015." prepared for U.S. Department of Energy by CH2M, Richland, WA.

Spane F.A. 1999. "Effects of Barometric Fluctuations on Well Water-Level Measurements and Aquifer Test Data." PNNL-13078, Pacific Northwest National Laboratory, Richland, Washington.

Spane, F.A. 2002. "Considering Barometric Pressure in Groundwater-Flow Investigations." *Water Resources Research*, 38(6):10.1029

Spane, FA and RD Mackley. 2011. "Removal of River-Stage Fluctuations from Well Response Using Multiple-Regression." *Ground Water* 49(6):794-807. doi:10.1111/j.1745-6584.2010.00780.x

Spane, FA and DR Newcomer. 2009. "Field Test Report: Preliminary Aquifer Test Characterization Results for Well 299-W15-225: Supporting Phase 1 of the 200-ZP-1 Groundwater Operable Unit Remedial Design." PNNL-18732, Pacific Northwest National Laboratory, Richland, Washington.

Truex, MJ, M Oostrom, KC Carroll, and GB Chronister. 2013. "Perched-Water Evaluation for the Deep Vadose Zone Beneath the B, BX and BY Tank Farms Area of the Hanford Site." PNNL-22499, Pacific Northwest National Laboratory, Richland, WA.