DOE/RL-2016-20
Revision 0

Calendar Year 2015 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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

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Executive Summary

This report presents the annual pump and treat (P&T) system performance evaluation for the 200-UP-1 and 200-ZP-1 Operable Units (OUs) at the Hanford Site for calendar year (CY) 2015. The 200-ZP-1 OU includes operation of the 200 West 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. These systems are operated by CH2M HILL Plateau Remediation Company for the U.S. Department of Energy.

The WMA S-SX groundwater extraction system operated throughout 2015 to remediate technetium-99 near the S-SX Tank Farms in the 200-UP-1 OU. Comingled chromium and nitrate plumes are also remediated in the process. Some carbon tetrachloride is also being removed from the aquifer. 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 CY 2015. When operating, typical flow rates for the system were 348 L/min (92 gallons per minute [gpm]), meeting the design nominal pumping rate of 303 L/min (80 gpm). The total volume of water extracted from the aquifer during 2015 was 183 million L (48.3 million gal), and the system removed 30.6 g (0.520 Ci) of technetium-99; 8.0 kg of chromium; 6,320 kg of nitrate; and 12.4 kg of carbon tetrachloride.

The U Plant area P&T and the iodine-129 plume hydraulic containment system began operating in CY 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 the year, the U Plant area P&T operated at an average rate of 468 L/min (124 gpm). The total volume of water extracted from the aquifer during 2015 was 65.4 million L (17.3 million gal), and the system removed 11.0 g (0.19 Ci) of technetium-99; 1.8 kg of uranium; 22,300 kg of nitrate; and 5.3 kg of carbon tetrachloride.

The iodine-129 plume hydraulic containment system consists of three hydraulic control injection wells for injecting treated water from the 200 West P&T to the east of the iodine-129 plume boundary. 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. Water level measurements will be used to determine the effectiveness of the hydraulic control remedy. Because the wells only operated for 2 months, it is too early to assess the effect of their operation on hydraulic gradients in the area and migration of the iodine-129 plume.

During CY 2015, the 200 West P&T sustained an average flow rate of 7,447 L/min (1,966 gpm). The 200 West P&T design currently consists of 26 extraction and 26 injection wells, with a design rate of approximately 9,464 L/min (2,500 gpm). As detailed in the 200-ZP-1 remedial design/remedial action work plan (DOE/RL-2008-78),[1] the 200 West P&T is being phased in, with the number of operating extraction and injection wells and the total operating capacity of the system increasing as needed. At the end of CY 2015, 26 extraction wells (including 3 wells from the S-SX Tank Farms, 2 wells from the U Plant P&T in the 200-UP-1 OU, and 1 well from the B Complex in the 200-BP-5 OU) and 26 injection wells were operating for the 200 West P&T. The total volume treated in CY 2015 through the 200 West P&T groundwater extraction system was 3,831.5 million L (1,011.5 million gal), removing 2,786 kg of carbon tetrachloride; 348,431 kg of nitrate; 84 kg of chromium (total and hexavalent); 11 kg of trichloroethene; and 109 g (1.87 Ci) of technetium-99. Iodine-129 removal was negligible, as the influent and effluent concentrations throughout 2015 were less than the detection limit of 0.6 pCi/L.

[1] 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.

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Terms

AWLN	automated water level network
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
CP Model	Central Plateau Model
CY	calendar year
DOE	U.S. Department of Energy
DS	decision statement
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FBR	fluidized bed reactor
FS	feasibility study
gpm	gallons per minute
HEIS	Hanford Environmental Information System
HQ	hazard quotient
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
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
QA	quality assurance
QC	quality control
RAO	remedial action objective
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
SST	single-shell tank
SVE	soil vapor extraction
TCE	trichloroethene
UCL_{95}	95 percent confidence limit
VOC	volatile organic compound
WMA	waste management area

1 Introduction

This report presents the calendar year (CY) 2015 operational results and evaluations for the 200-UP-1 and 200-ZP-1 Groundwater Operable Unit (OU) pump and treat (P&T) systems at the Hanford Site. For CY 2015, this encompassed operation of the 200 West P&T Facility, which includes the 200-ZP-1 OU extraction and injection system, 200-UP-1 OU Waste Management Area (WMA) S-SX groundwater extraction system, U Plant area P&T, and iodine-129 plume hydraulic containment injection wells. 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, WMA S-SX groundwater extraction system, U Plant area P&T, iodine-129 hydraulic containment injection wells, and associated waste sites.

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 focuses on uranium and technetium-99 removal from the aquifer, consists of two extraction wells and aboveground, dual-walled pipelines 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 also completed during 2015. The U Plant area P&T system began operating during September 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 will be used to determine the effectiveness of the hydraulic control remedy. Because the wells only operated for 2 months of 2015, it is too early for this annual report to assess the effect of their operation on hydraulic gradients in the area and migration of the iodine-129 plume. Groundwater remediation of the 200-UP-1 OU is addressed by the 200-UP-1 record of decision (ROD) (EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*).

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 percent 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. The 200-ZP-1 ROD (EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Operable Unit Superfund Site Benton County, Washington*) provides the regulatory framework for remediation of the 200-ZP-1 OU.

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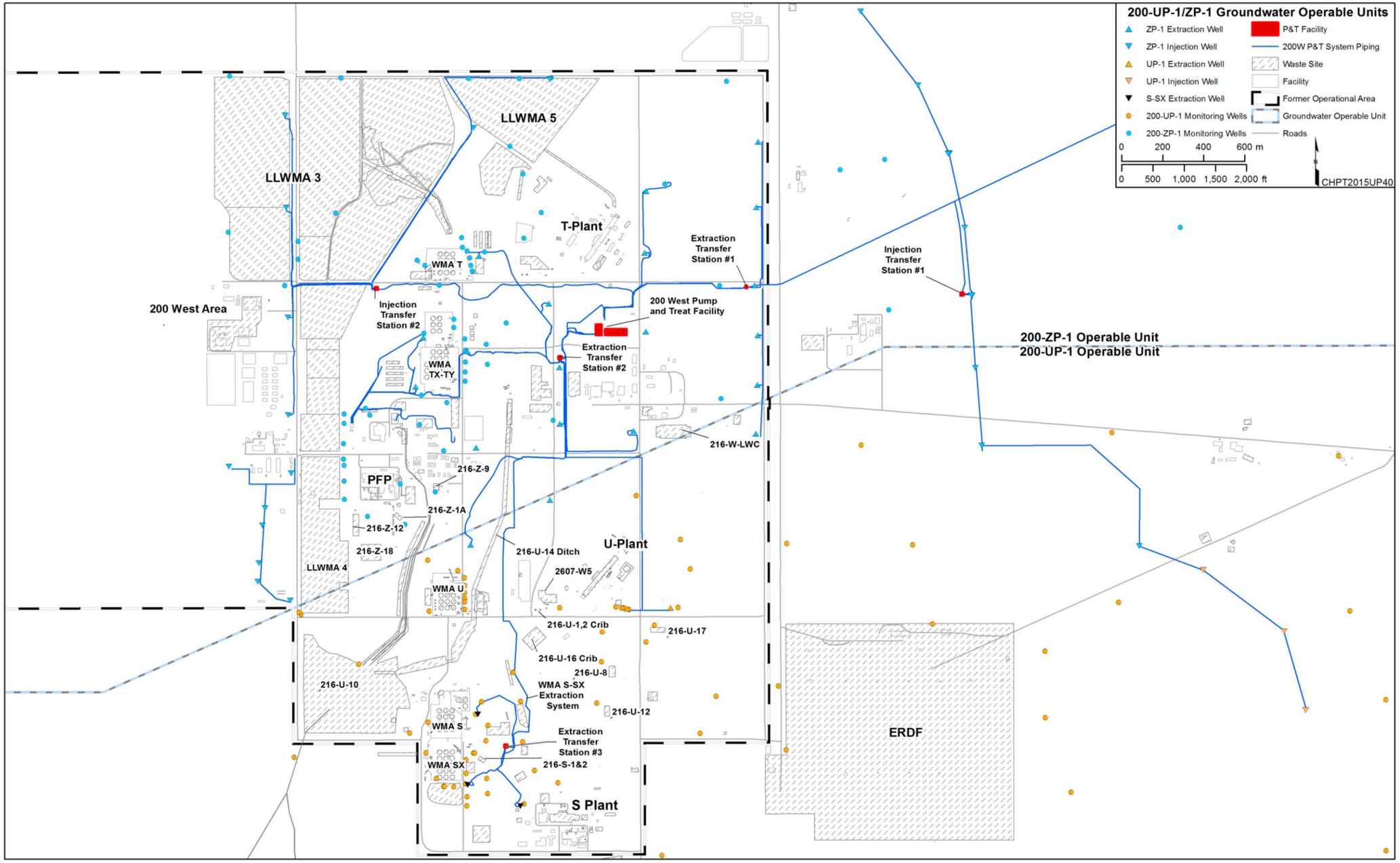

ERDF = Environmental Restoration Disposal Facility LLWMA = low-level waste management area PFP = Plutonium Finishing Plant

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

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During CY 2015, facility modifications to the 200 West P&T were completed to connect the U Plant area P&T extraction wells and one well in the 200-BP-5 OU[2] for treatment through the 200 West P&T and install the uranium IX train for the U Plant area P&T system and 200-BP-5 extraction well. A new extraction well for 200-ZP-1 drilled in 2013 was brought online in 2015.

Chapter 2 documents performance of 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 3 describes the 200-ZP-1 groundwater extraction system for 2015, including the following information:

- Activities and developments during 2015
- 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 and recommendations (including recommendations for changes to system configuration and operating parameters, as well as system maintenance)

Additional information on the nature and extent of groundwater contamination is presented in DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*. Appendix F of DOE/RL-2016-09 provides a discussion of quality assurance (QA) and quality control (QC) as applied to groundwater sampling and analysis during 2015.

[2] Performance of the 200-BP-5 extraction system is documented in DOE/RL-2015-75, *Aquifer Treatability Test Report for the 200-BP-5 Groundwater Operable Unit*.

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2 200-UP-1 Operable Unit Remedial Actions

This chapter discusses groundwater remedial actions within the 200-UP-1 OU. At the end of 2015, 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 remedial action objectives (RAOs) and to assess remedy performance so operational improvements can be made, if needed. This chapter also addresses planning for characterization of 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 (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 2-1 lists cleanup levels specified in the 200-UP-1 ROD (EPA et al., 2012). The remedial design/remedial action work plan (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 performance monitoring plan (PMP) (DOE/RL-2015-14, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*), which was released during 2015. Sampling requirements to meet the PMP will be 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 2015.

Section 2.1 provides an overview of the hydraulic monitoring network for the 200-UP-1 OU and methods of data analysis to determine capture. Sections 2.2, 2.3, and 2.4 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 2.5 describes plans to characterize the chromium plume southeast of the 200 West Area, and Section 2.6 addresses MNA. Section 2.7 references where sampling QA/QC information is reported, and cost information is provided in Section 2.8. Sections 2.9 and 2.10 include the conclusions and recommendations, respectively.

2.1 200-UP-1 Hydraulic Monitoring Overview

This section provides an overview of the hydraulic monitoring program for 200-UP-1 and presents the 2015 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 2-1). 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 2-2 and 2-3), and the data are analyzed for capture analyses. During the second half of 2015, 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. Quarterly measurements were collected for the WMA S-SX system during the first half of the year. 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 2-2).

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, *Hybrid Analytic Element Universal Kriging Interpolation Technique Built in Open Source R Environment*). For MEUK, 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). 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 detail on MEUK methodology can be found in Section 3.2.1 of the PMP (DOE/RL-2015-14).

Table 2-1. 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
				Non-carcinogens 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[d]	µg/L	99	100	24,000	N/A	100
Hexavalent Chromium[d]	µg/L	52	N/A[e]	48	N/A	48
Carbon Tetrachloride	µg/L	189	5	5.6	0.34[f]	3.4[g]

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, "Model Toxics Control Act—Cleanup."

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. The mobile form of chromium in Hanford Site groundwater is hexavalent chromium. Groundwater samples have been analyzed for chromium by the analytical laboratories as either total chromium or hexavalent chromium. Both methods yield similar results, although there can be differences caused by normal analytical variability or sample turbidity. Therefore, although total chromium and hexavalent chromium are listed as separate COCs, they represent the same constituent in Hanford Site groundwater. The effective cleanup level for chromium is the hexavalent chromium standard of 48 µg/L because it is more restrictive.

e. There is no federal DWS for hexavalent chromium.

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

g. 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."

DWS = drinking water standard

EPA = U.S. Environmental Protection Agency

N/A = not applicable

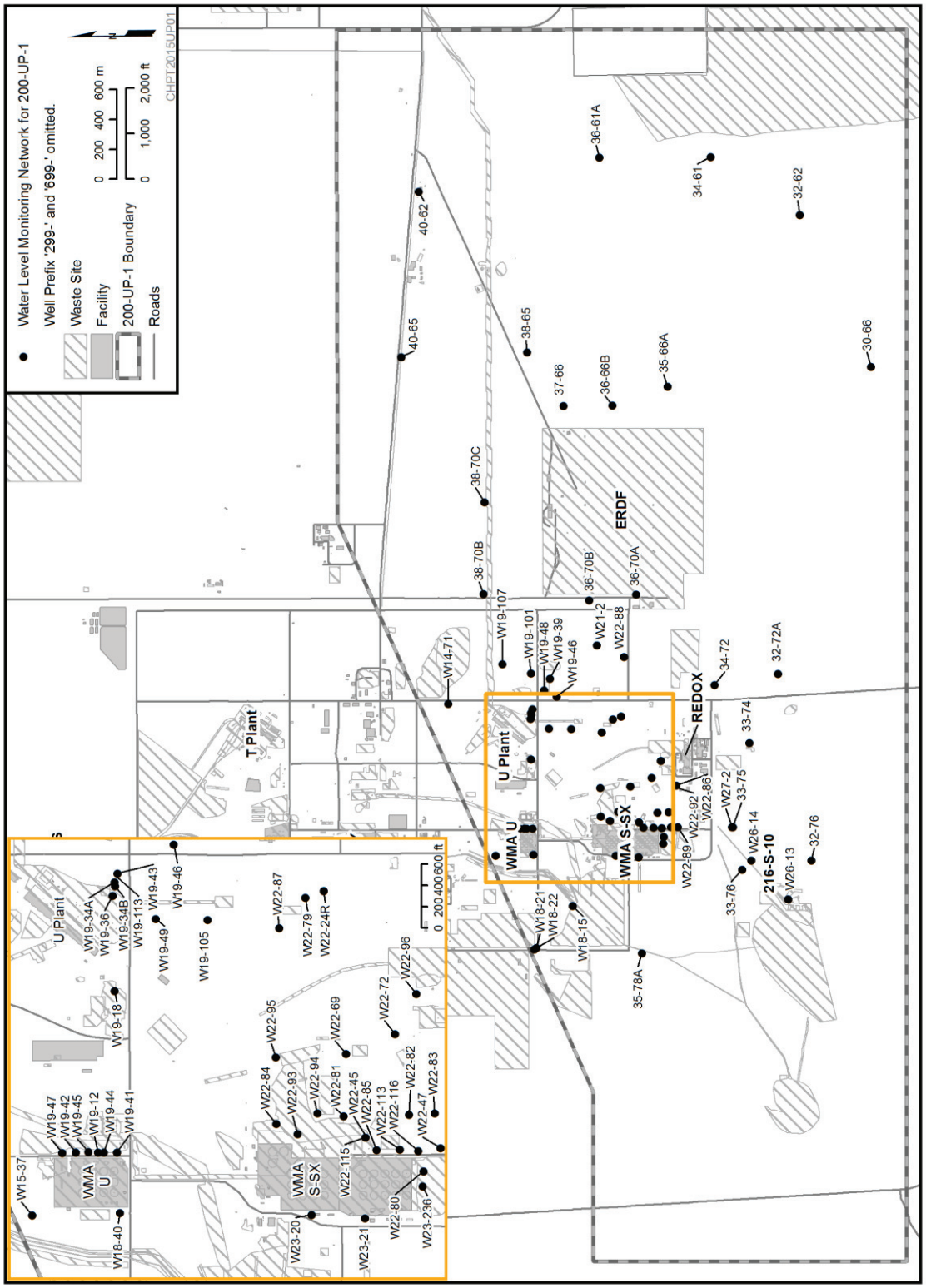


Figure 2-1. Regional Water Level Monitoring Network for the 200-UP-1 Operable Unit

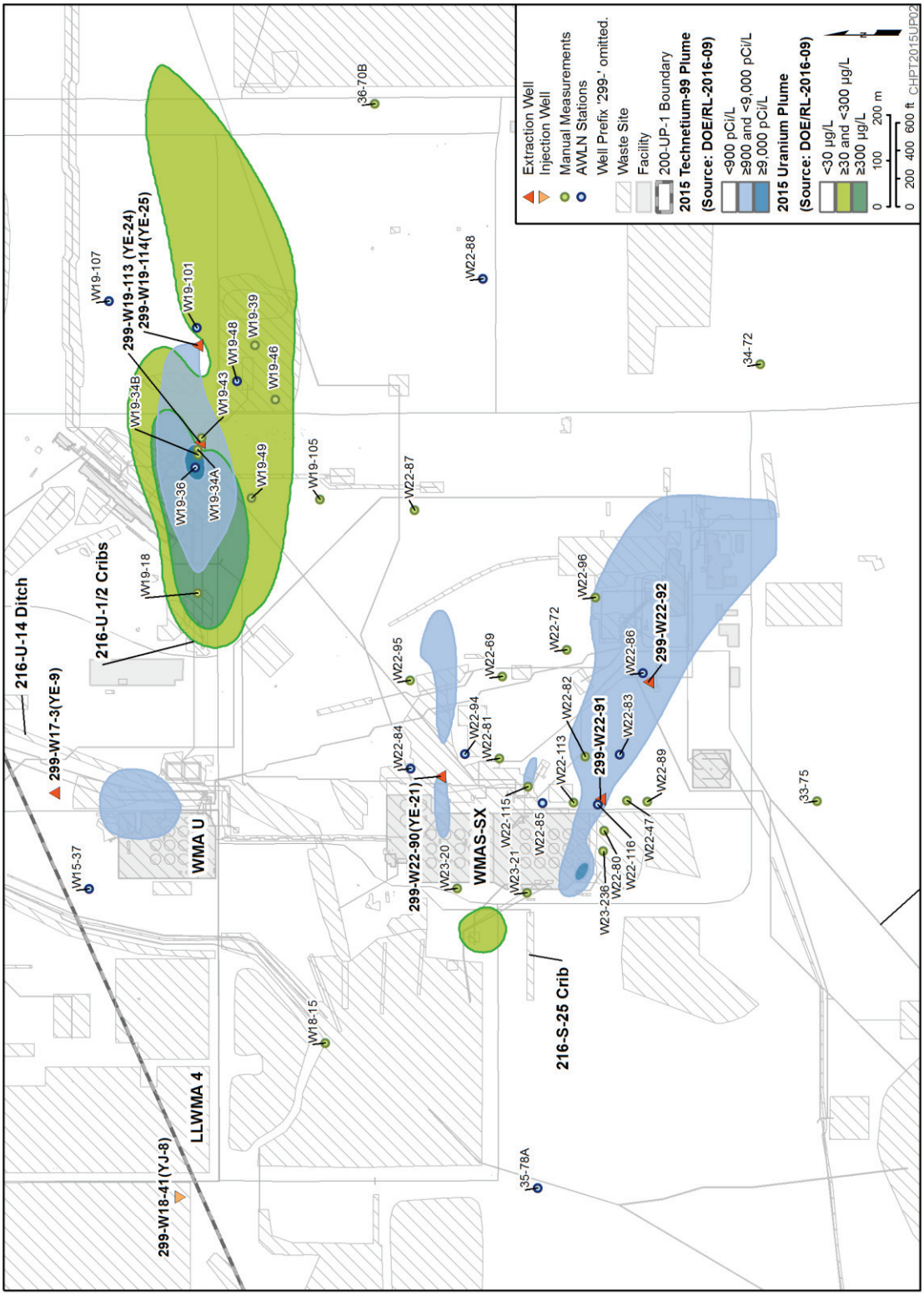


Figure 2-2. Water Level Monitoring Network for the WMA S-SX and U Plant Area Active Remedies

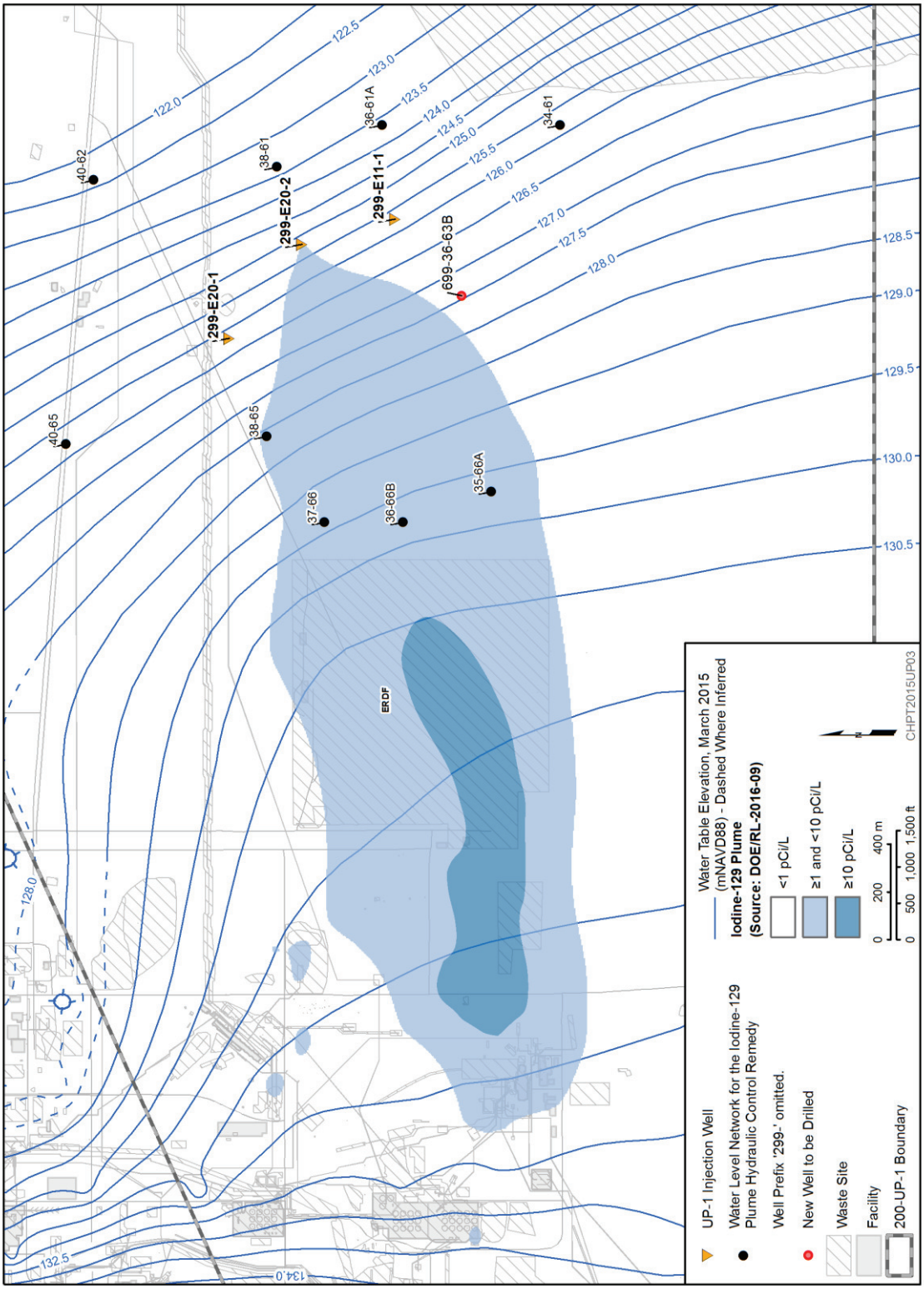


Figure 2-3. Water Level Monitoring Network for the Iodine-129 Plume Hydraulic Containment Remedy

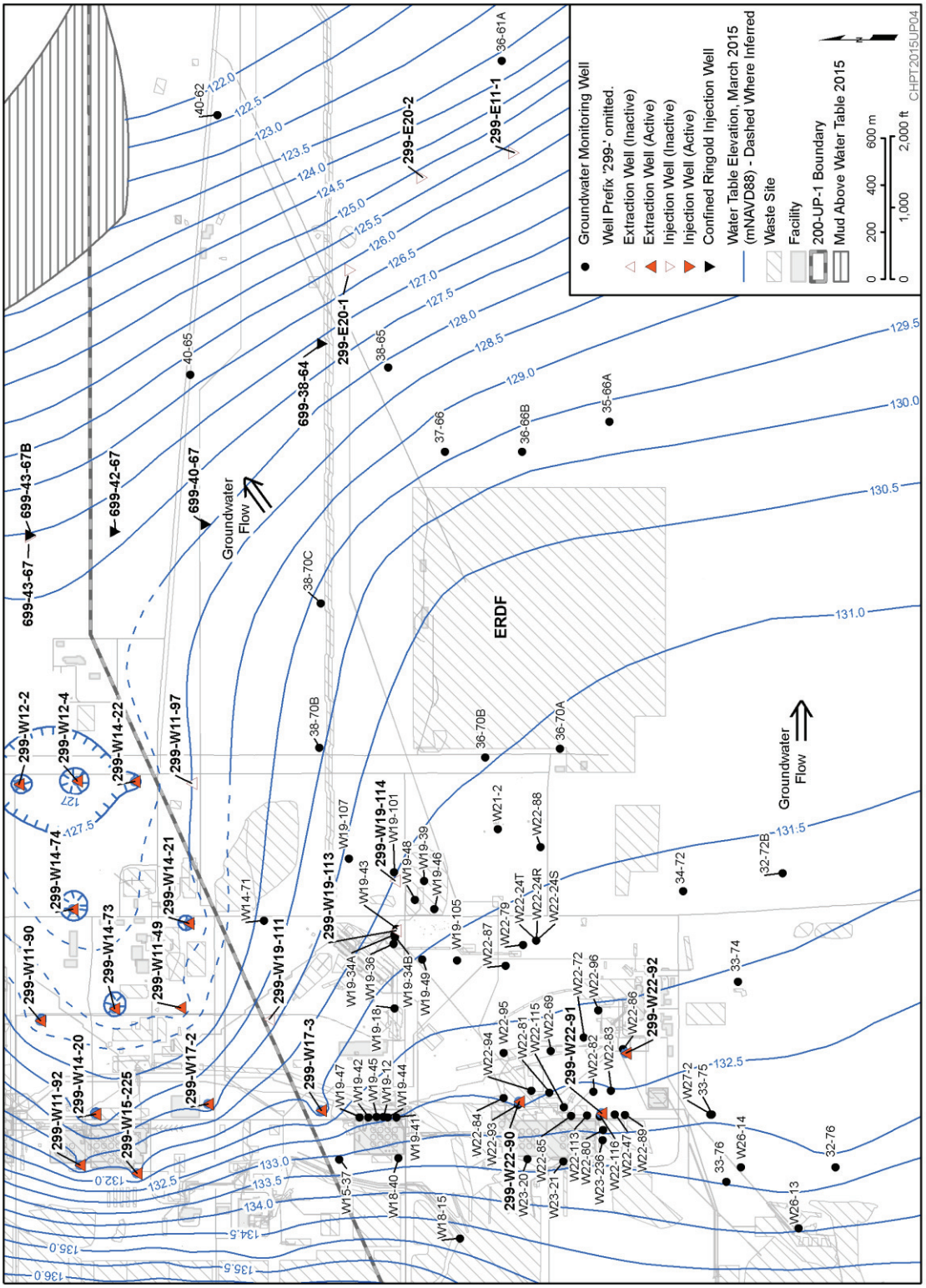
The 200-UP-1 regional water table map for March 2015 is presented in Figure 2-4. This map provides the context for more detailed hydraulic analyses of the active remedies presented in the following sections. The regional map was prepared by a combination of kriging near the WMA S-SX groundwater extraction system and manual contouring elsewhere (kriging was not used for the U Plant and iodine-129 plume areas because these systems began operating after March 2015; these areas were contoured manually). The kriging methodology used is documented in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*. The methodology 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. Since 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 2-4). The magnitude of the hydraulic gradient becomes higher toward the east. This is caused, at least partly, by a decrease in the aquifer thickness and the resulting 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 thinner aquifer. Hydraulic conductivity of the aquifer sediments could also decrease toward the east, which would also contribute to the larger hydraulic gradient magnitude. In the north central portion of the OU, including within the U Plant area, the groundwater flow direction has been substantially altered by the 200 West P&T in the 200-ZP-1 OU. This system 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.

2.2 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-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*). 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 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 2-4. Water Table Map for the 200-UP-1 Operable Unit, March 2015

To address increasing technetium-99 concentrations in groundwater beneath and downgradient of the S-SX Tank Farms, the plume is being remediated by groundwater extraction and treatment. 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 2-5). 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 volatile organic compounds (VOCs).

Groundwater pumped by the WMA S-SX extraction wells is combined with groundwater pumped by the 200-ZP-1 and 200-BP-5 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 Section 3.1 (Chapter 3).

2.2.1 Remedial System Operation

The WMA S-SX groundwater extraction system operated more than 90 percent of the time during 2015. The extraction wells were periodically shut down for system maintenance, but almost all of these instances lasted less than 1 day. Water was pumped from the aquifer every day except one during 2015.

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.

2.2.1.1 Extraction Well Flow Rates

Weekly average flow rates per extraction well are shown in Figure 2-6. Average flow rates during the year were 89 L/min (24 gallons per minute [gpm]) for 299-W22-90, 130 L/min (34 gpm) for 299-W22-91, and 129 L/min (34 gpm) for 299-W22-92. This yielded a combined average flow rate of 348 L/min (92 gpm), 115 percent of the design nominal pumping rate of 303 L/min (80 gpm). This was an increase of 41 L/min (11 gpm) over the average flow rates for 2014. The total volume of water extracted from the aquifer during 2015 was 183 million L (48.3 million gal), and the total since startup in July 2012 was 510 million L (135 million gal).

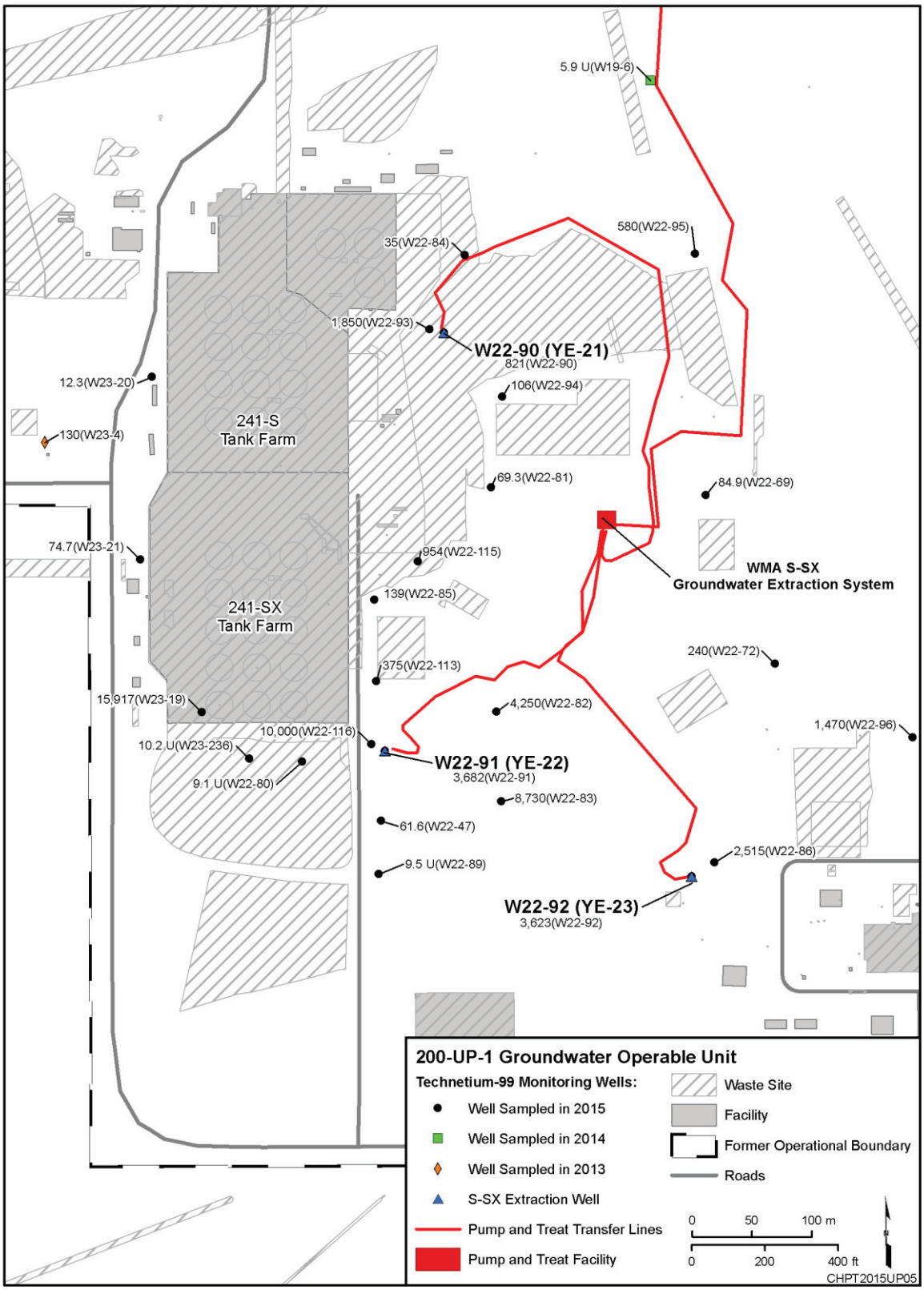


Figure 2-5. WMA S-SX Groundwater Extraction System and Monitoring Wells

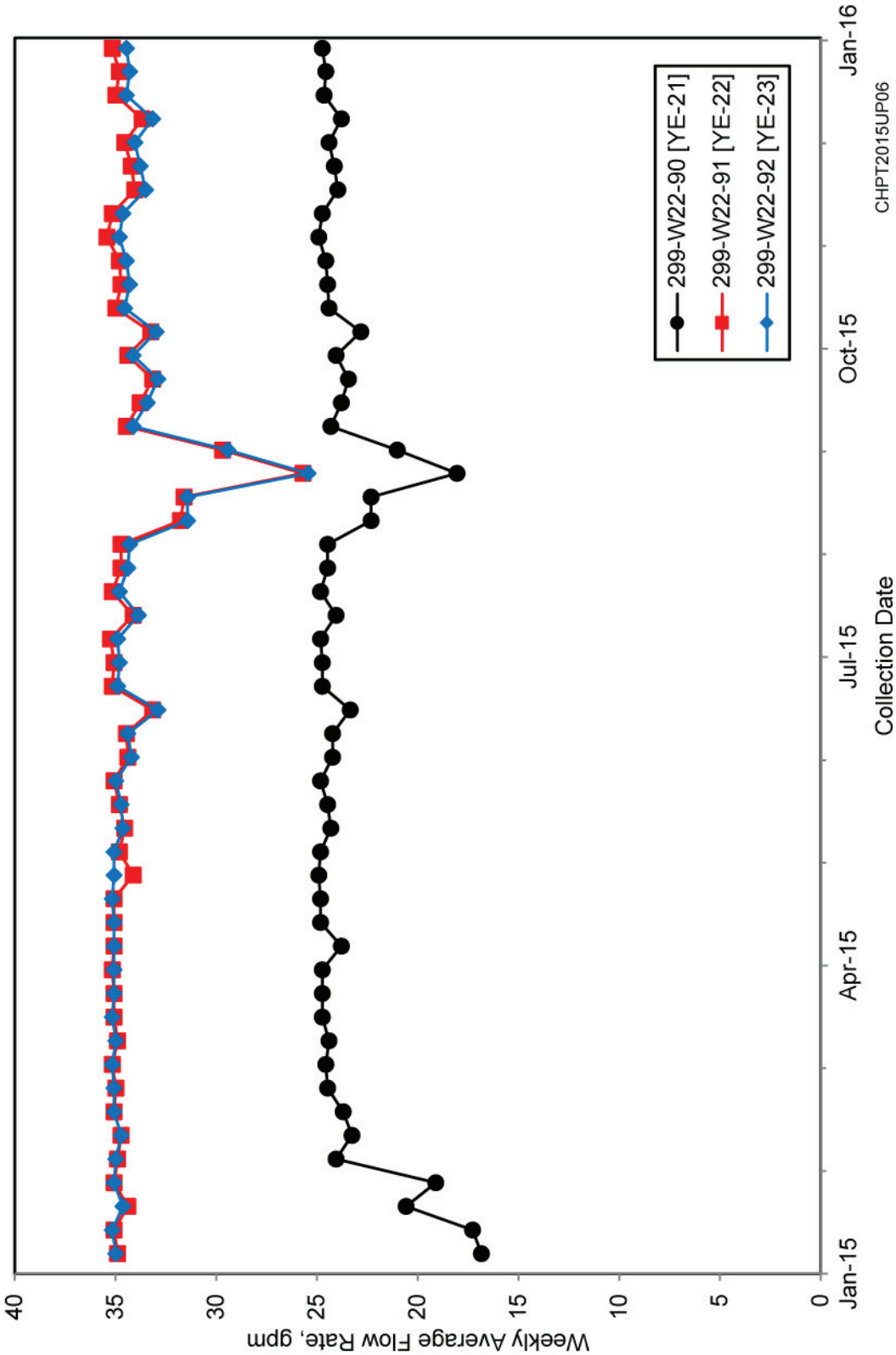


Figure 2-6. Weekly Average Pumping Rates during 2015 for the WMA S-SX Groundwater Extraction System

2.2.1.2 Extraction Well Mass Removal

The WMA S-SX extraction wells are sampled quarterly, and the results for 2015 are provided in Table 2-2. 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 tetrachloride0, removed from the aquifer (Table 2-3). Although tritium is present in the groundwater, the amount of tritium removed from the aquifer is not shown in Table 2-3 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 (Table 3-5 in Chapter 3) ranged from 2,390 to 2,960 pCi/L during 2015.[3]

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

Well Name	Constituent	1/5/2015 Result	4/7/2015 Result	7/7/2015 Result	10/15/2015 Result
299-W22-90 (YE-21)	Carbon Tetrachloride (µg/L)	81[b]	68	67	72
	Chromium (µg/L)[a]	58[b]	49.8	48.7	46
	Nitrate (mg/L as NO_3)	30.9[b]	29.6	28.4	27.4
	Technetium-99 (pCi/L)	901[b]	791	796	756
299-W22-91 (YE-22)	Carbon Tetrachloride (µg/L)	64	65	68[b]	71
	Chromium (µg/L)[a]	44.6	42.2	44.3[b]	41
	Nitrate (mg/L as NO_3)	37.6	35.3	34.1[b]	31.9
	Technetium-99 (pCi/L)	4,060	3,920	3,580[b]	3,480
299-W22-92 (YE-23)	Carbon Tetrachloride (µg/L)	63	69	62	67
	Chromium (µg/L)[a]	66.3	50.5	46.9	41
	Nitrate (mg/L as NO_3)	41.7	40.7	39.5	37.2
	Technetium-99 (pCi/L)	4,210	3,920	3,300	3,060

a. Maximum of total chromium and hexavalent chromium from unfiltered samples.

b. Maximum of duplicate sample results.

Table 2-3. Contaminant Mass (or Activity) Removed from the Aquifer by the WMA S-SX Groundwater Extraction System

Constituent	Mass (Activity) Removed during 2015	Mass (Activity) Removed since Startup
Technetium-99, g (Ci)	30.6 (0.520)	128.6 (2.18)
Chromium, kg	8.0	36.1
Nitrate (as NO_3), kg	6,320	22,600

[3] In the 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 2-3. Contaminant Mass (or Activity) Removed from the Aquifer by the WMA S-SX Groundwater Extraction System

Constituent	Mass (Activity) Removed during 2015	Mass (Activity) Removed since Startup
Carbon Tetrachloride, kg*	12.4	39.5

* Due to a calculation error, the amount of carbon tetrachloride removed from the aquifer was overestimated in previous years. The corrected numbers are 2.34 kg in 2012, 11.9 kg in 2013, and 12.9 kg in 2014.

2.2.1.3 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 3.1 (Chapter 3) provides a description of the treatment system and its performance during 2015. The technetium-99 removal efficiency for the entire system averaged 95 percent during 2015 (Table 3-2 [Chapter 3]), 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) (Table 3-5 [Chapter 3]).

2.2.2 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 2015.

2.2.2.1 Water Level Measurements

During 2015, synoptic manual depth-to-water measurements were collected quarterly during the first half of the year (i.e., March and June) and then monthly beginning in July 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 2-2). 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 monitoring networks.

2.2.2.2 Hydraulic Capture Analysis

Groundwater levels and pumping rates were interpreted to estimate the hydraulic capture zone of the WMA S-SX groundwater extraction system. When generating water table maps for capture zone analyses in past years, several wells had to be excluded because they resulted in hydrologically questionable water level contour inflections and corresponding capture zones. It was suspected that some of the water level measurements causing the questionable capture zones had a systematic bias created by deviations of the

paths of the wellbores from vertical (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*). Wells that deviate from vertical yield depth-to-water measurements larger than the true vertical depth to water; thus, calculated water level elevations are lower than the true water level elevation. This potential source of error was addressed during 2014 by performing borehole path surveys using a gyroscope. While this improved the capture zone results, it did not entirely solve the problem; some wells still had to be removed from the analyses for 2014. During 2015, well casings for several wells were resurveyed to improve the accuracy of the water level elevation determinations. The new surveys were within 0.005 m of the old surveys for all wells, except for 299-W23-15 where the difference was 0.036 m (Table 2-4). After applying the new casing survey to the water level data for 299-W23-15, the capture analyses for 2015 were very reasonable, and all wells were used in the analysis.

Table 2-4. WMA S-SX Monitoring Well Casing Elevation Survey Results

Well Name	Previous Casing Elevation (m NAVD88)	Resurveyed Casing Elevation (m NAVD88)	Difference (m)
299-W22-80	200.851	200.853	+0.002
299-W23-15	200.843	200.807	-0.036
299-W23-20	203.795	203.800	+0.005
299-W23-21	203.352	203.356	+0.004

Reference: NAVD88 = *North American Vertical Datum of 1988* (vertical control).

Figure 2-7 depicts the estimated capture zone developed groundwater extraction at the WMA S-SX system during March 2015, as well as the technetium-99 plume in groundwater. The capture zone was estimated by mapping the groundwater elevation data for March 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]). Differences between the mapped and measured water levels ranged from 0 to 7 cm (0 to 0.07 m) and averaged 2 cm (0.02 m), indicating that the mapped water table closely matches the water level measurements. 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 2015 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 2015 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 2-7 indicates that the system will capture most portions of the technetium-99 plumes that occur between the extraction wells and tank farms at the 900 pCi/L concentration level. 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 percent 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*).

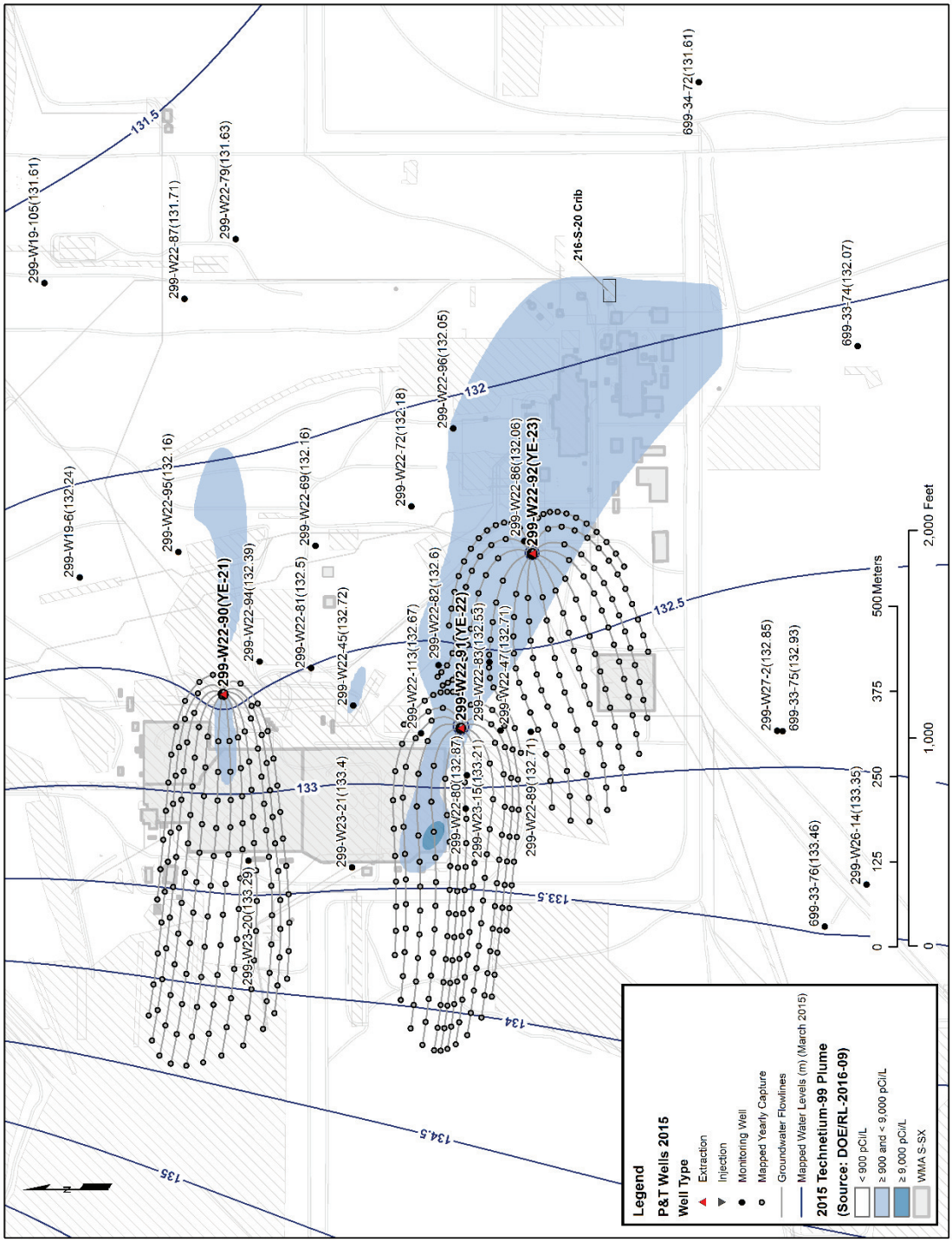


Figure 2-7. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System under March 2015 Conditions (Steady-State Assumption) Compared to the Technetium-99 Plumes

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 2-8 and 2-9 show the March 2015 capture zones with the chromium and nitrate plumes (the small chromium and nitrate plumes at the 216-S-20 Crib shown in Figures 2-8 and 2-9 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.

2.2.3 Contaminant Monitoring

This section summarizes the 2015 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/RA work plan (DOE/RL-2013-07). Discussions of recent monitoring results for the entire OU are provided in DOE/RL-2016-09.

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 2015 are presented and compared to baseline concentrations. When more than one sample result was available in a well, the last sample collected during 2015 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-2016-09. Section 2.3.2 of DOE/RL-2013-14 contains background information on the plumes, including sources and historical plume trends.

2.2.3.1 Technetium-99, Chromium, and Nitrate Monitoring Results

Technetium-99, chromium, and nitrate are discussed together 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 also 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: (1) inductively coupled plasma, which yields a result for total chromium (i.e., trivalent and hexavalent chromium combined); and (2) a colorimetric method (ultraviolet/visible light absorption), which yields a result for only the hexavalent form. Therefore, the Hanford Environmental Information System (HEIS) database includes results for both total chromium and hexavalent chromium. In Hanford Site groundwater, both have similar concentrations within any given well because the mobile form of chromium is hexavalent (i.e., the filtered total chromium results by inductively coupled plasma are equivalent to the hexavalent chromium results by the colorimetric method). Total chromium and hexavalent chromium have different cleanup levels specified in the 200-UP-1 ROD (EPA et al., 2012) (100 and 48 µg/L, respectively). For discussion purposes in this chapter, sample results for total chromium and hexavalent chromium will be referred to together simply as “chromium,” and the effective cleanup level is 48 µg/L because it is more restrictive (it should be noted that when chromium sampling is performed for the 200-UP-1 OU under DOE/RL-2015-14, both total and hexavalent chromium are analyzed).

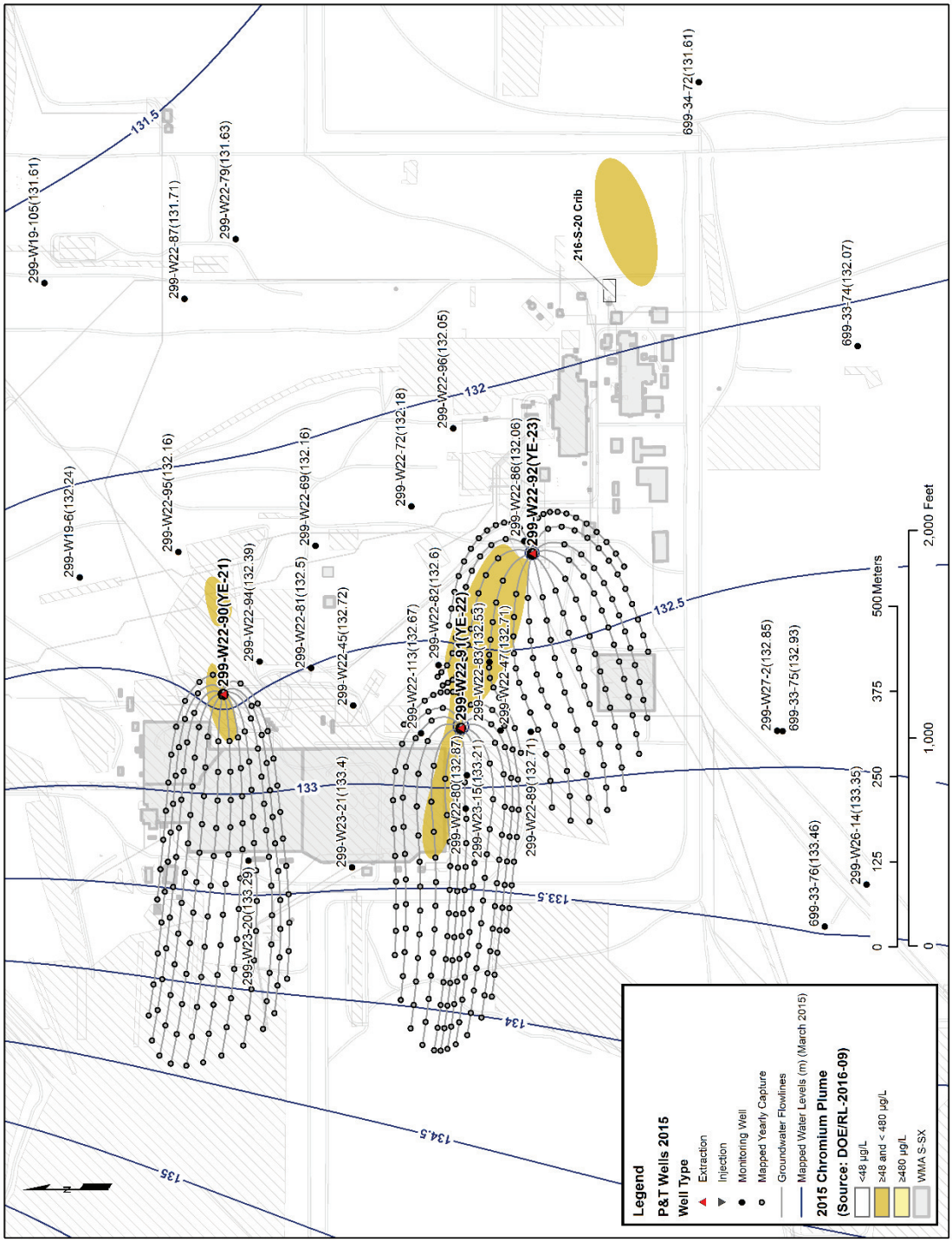


Figure 2-8. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System under March 2015 Conditions (Steady-State Assumption) Compared to the Chromium Plumes

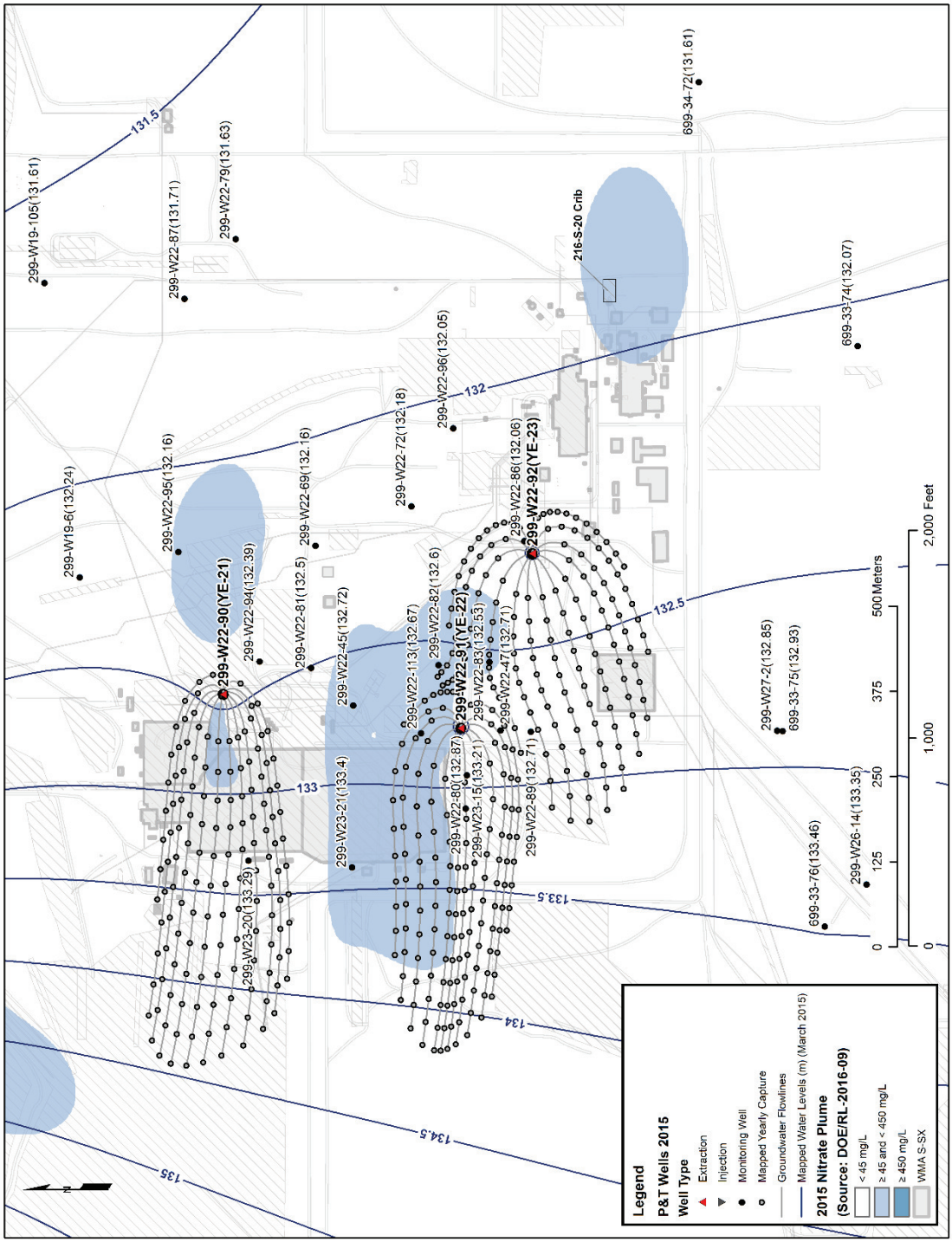


Figure 2-9. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System under March 2015 Conditions (Steady-State Assumption) Compared to the Nitrate Plumes

The S and SX Tank Farms are both sources of technetium-99, chromium, and nitrate contamination to the groundwater (Figures 2-10, 2-11, and 2-12). The plumes from the S Tank Farm (northern plumes in Figures 2-10, 2-11, and 2-12) extend downgradient (eastward) past 299-W22-26 (now dry) at concentrations above their respective cleanup levels (900 pCi/L for technetium-99, 48 µg/L for chromium, and 45 mg/L for nitrate). These plumes are now divided into two parts due to groundwater extraction at 299-W22-90. Depth-discrete sample results during drilling of this well indicate that the technetium-99 and nitrate plumes extend to a depth of 10 m (33 ft) below the water table at concentrations above cleanup levels (DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*). A similar depth is presumed for the chromium plume. The technetium-99 plume from the SX Tank Farm (southern plume in Figure 2-10) extends approximately 800 m (2,600 ft) toward the east and southeast from the source. The chromium and nitrate plumes extend east from the SX Tank Farm to near 299-W22-86 (southern plumes in Figures 2-11 and 2-12). 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 2015 technetium-99, 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 2-5, 2-6, and 2-7, respectively. These comparisons are also shown in Figures 2-13, 2-14, and 2-15, respectively. Several of the WMA S-SX monitoring wells have become dry in recent years or are nearly dry. The following replacement wells have been installed: 299-W22-93 replaced 299-W22-44 in 2015, 299-W22-94 replaced 299-W22-48 in 2013, 299-W22-95 replaced 299-W22-26 in 2013, 299-W22-113 replaced 299-W22-49 in 2014, 299-W22-115 replaced 299-W22-45 in 2015, 299-W22-116 replaced 299-W22-50 in 2015, and 299-W23-236 replaced 299-W23-15 in 2015[4]. 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 2-5, 2-6, and 2-7 (correlations of a replacement well to the dry well it replaced are given in the table footnotes).

Concentrations have declined in a majority of wells that had baseline concentrations above a cleanup level. Concentrations have declined in 6 of the 9 wells with a baseline technetium-99 concentration above the 900 pCi/L cleanup level, in 5 of the 6 wells with a baseline chromium concentration above the 48 µg/L cleanup level, and in all 12 wells with a baseline nitrate concentration above the 45 mg/L cleanup level. Concentrations have declined to below the technetium-99 cleanup level in two wells (299-W22-47 and 299-W22-113), to below the chromium cleanup level in two wells (299-W22-47 and 299-W22-86), and to below the nitrate cleanup level in 4 wells (299-W22-47, 299-W22-85, 299-W22-86, and 299-W22-94). Concentrations have increased above the technetium-99 cleanup level in 299-W22-115 and above the nitrate cleanup level in 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.

[4] 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.

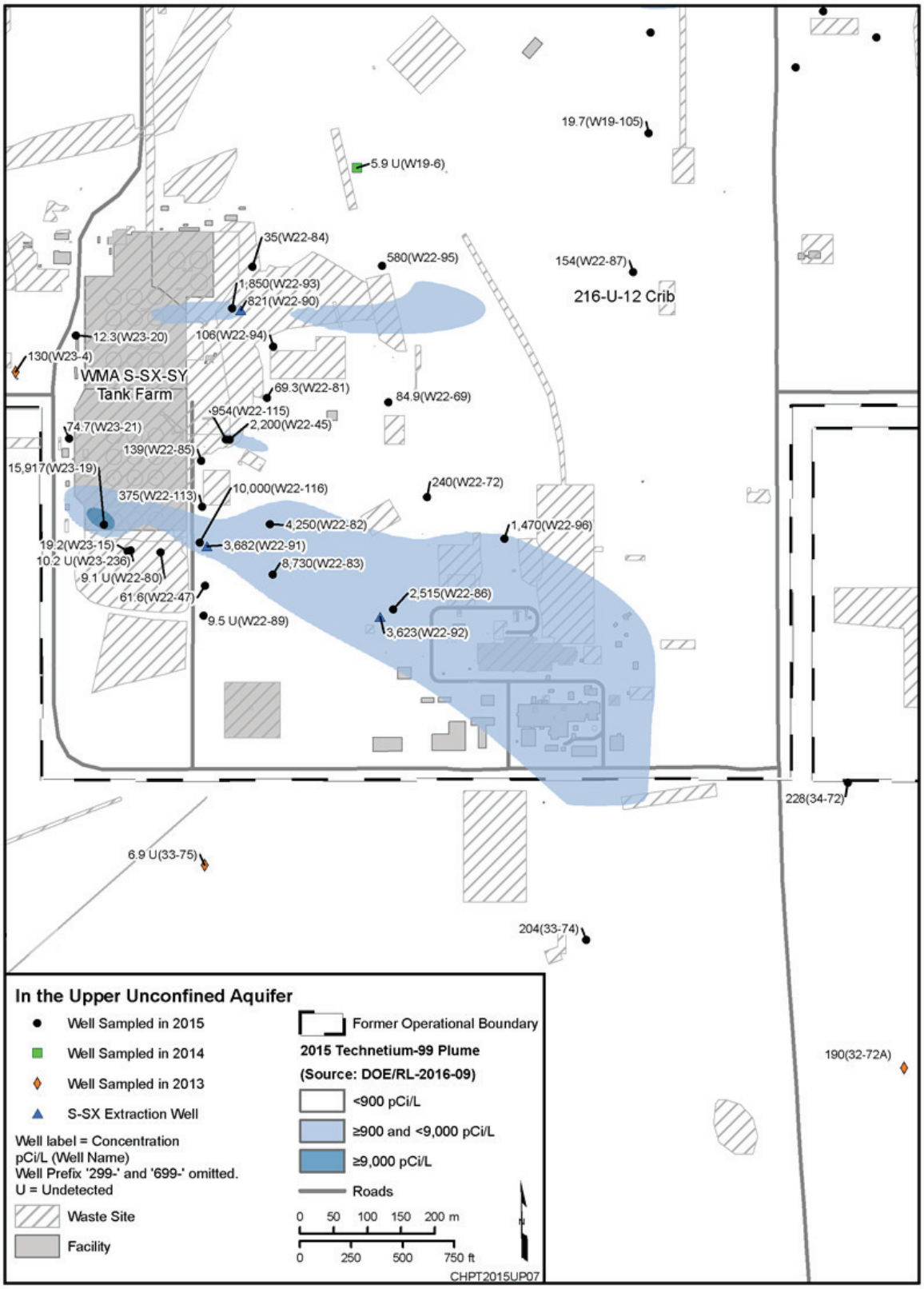


Figure 2-10. Technetium-99 Plumes in Groundwater near the S-SX Tank Farms, 2015

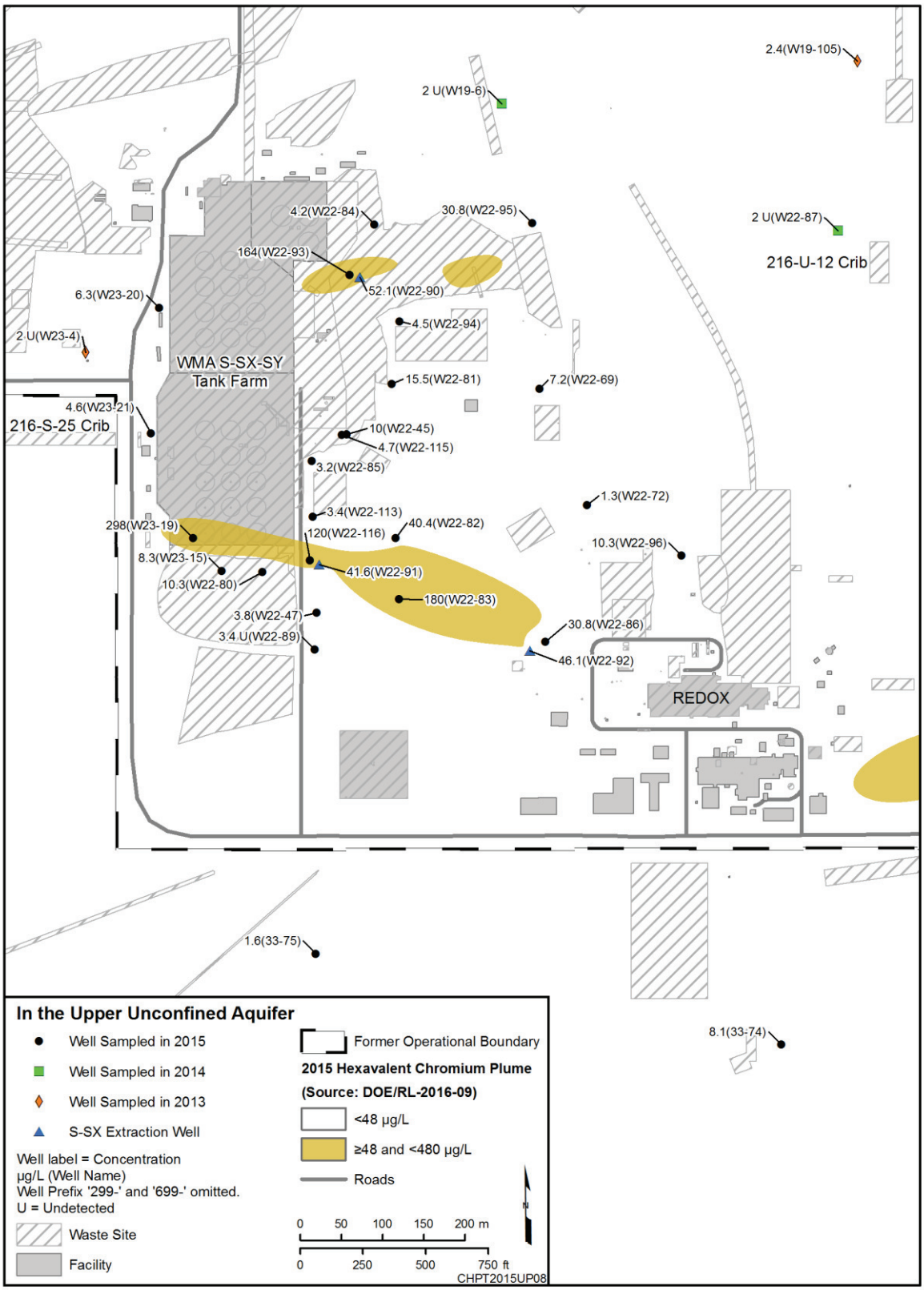


Figure 2-11. Chromium Plumes in Groundwater near the S-SX Tank Farms, 2015

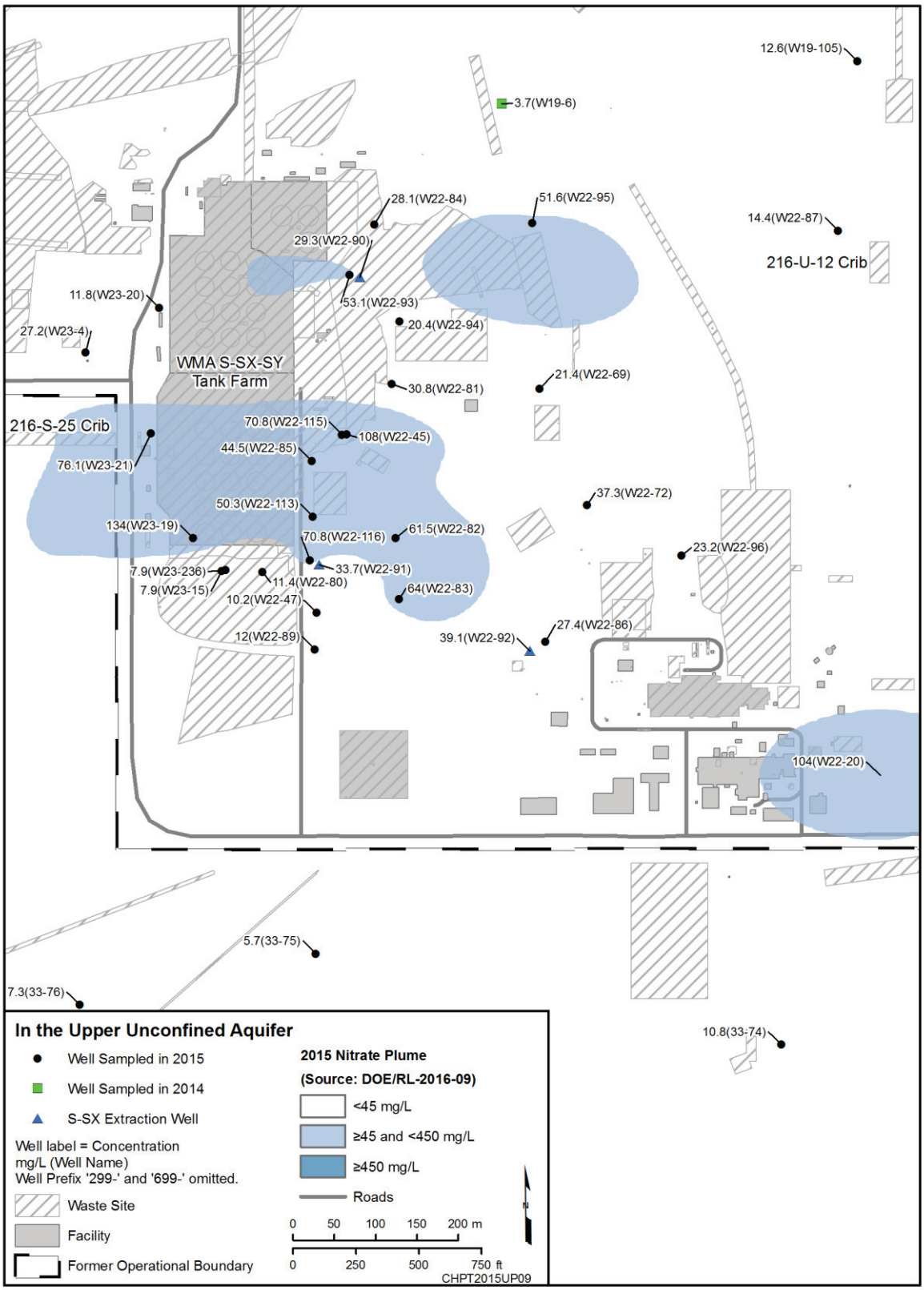


Figure 2-12. Nitrate Plume in Groundwater near the S-SX Tank Farms, 2015

Table 2-5. Comparison of 2015 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)	2015 Technetium-99 (pCi/L)[a]	Difference (%)[b]
299-W22-47	15,000	55.8	-100
299-W22-69	220	84.9	-61
299-W22-72	135	240	+78
299-W22-80	19	<9.1[c]	—
299-W22-81	67.5	69.3	+3
299-W22-82	2,900	4,250	+47
299-W22-83	17,700	7,440	-58
299-W22-84	630	35.0	-94
299-W22-85	140	86.8	-38
299-W22-86	11,000	2,910	-74
299-W22-89	<6.5[c]	<9.5[c]	—
299-W22-93[d]	10,500[d]	1,850	-82
299-W22-94[e]	880[e]	106	-88
299-W22-95[f]	310[f]	568	+83
299-W22-96	1,020	1,470	+44
299-W22-113[g]	2,300[g]	493	-79
299-W22-115[h]	520[h]	954	+84
299-W22-116[i]	5,750[i]	10,000	+74
299-W23-19	45,000	16,600	-63
299-W23-20	6.70	12.3	—
299-W23-21	86.2	74.7	-13
299-W23-236[j]	18.0[j]	<10.2[c]	—

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 2015, the result shown is from the last sample of the year.

b. Differences are shown for only those wells with a baseline or 2015 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.

Table 2-6. Comparison of 2015 Chromium Sample Results from Monitoring Wells in the S-SX Tank Farms Vicinity to Baseline Concentrations

Well Name	Baseline (2012) Chromium (µg/L)	2015 Chromium (µg/L)[a]	Difference (%)[b]
299-W22-47	183	3.73	-98
299-W22-69	12.5	7.2	—
299-W22-72	<5.0[c]	1.32	—
299-W22-80	25.4	10.3	-59
299-W22-81	9.7	15.5	—
299-W22-82	32.1	40.4	+26
299-W22-83	253	181	-29
299-W22-84	47.5	4.17	-91
299-W22-85	6.3	2.9	—
299-W22-86	149	33.3	-78
299-W22-89	<5.0[c]	<3.4[c]	—
299-W22-93[d]	353	164	-54
299-W22-94[e]	23.4[g]	4.38	—
299-W22-95[f]	9.9[i]	35.8	+262
299-W22-96	5.1	10.3	+102
299-W22-113[g]	8.2	2.6	—
299-W22-115[h]	8.4	4.7	—
299-W22-116[i]	63.7	120	+88
299-W23-15	6	8.3	—
299-W23-19	1,010	205	-80
299-W23-20	<5.0[c]	6.3	—
299-W23-21	6.3	4.61	—

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 2015, the result shown is from the last sample of the year.

b. Differences are shown for only those wells with a baseline or 2015 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 to 3.4 µg/L in 2015.

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

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.

Table 2-7. 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)	2015 Nitrate (mg/L as NO_3)[a]	Difference (%)
299-W22-47	99.4	10.2	-90
299-W22-69	20.7	21.4	+3
299-W22-72	29.6	37.3	+26
299-W22-80	12.8	11.4	-11
299-W22-81	27.4	30.8	+12
299-W22-82	62.0	61.5	-1
299-W22-83	117	57.5	-51
299-W22-84	35.3	28.1	-20
299-W22-85	63.7	44.3	-31
299-W22-86	70.6	31.9	-55
299-W22-89	13.1	12.0	-8
299-W22-93[b]	177[b]	53.1	-70
299-W22-94[c]	51.4[c]	21.2	-59
299-W22-95[d]	39.8[d]	53.1	+33
299-W22-96	18.3	23.2	+27
299-W22-113[e]	84.6[e]	48.7	-42
299-W22-115[f]	79.2[f]	70.8	-11
299-W22-116[g]	71.8[g]	70.8	-1
299-W23-19	355	124	-65
299-W23-20	10.4	11.8	+14
299-W23-21	84.6	76.1	-10
299-W23-236[h]	7.24[h]	7.88	+9

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 2015, 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.

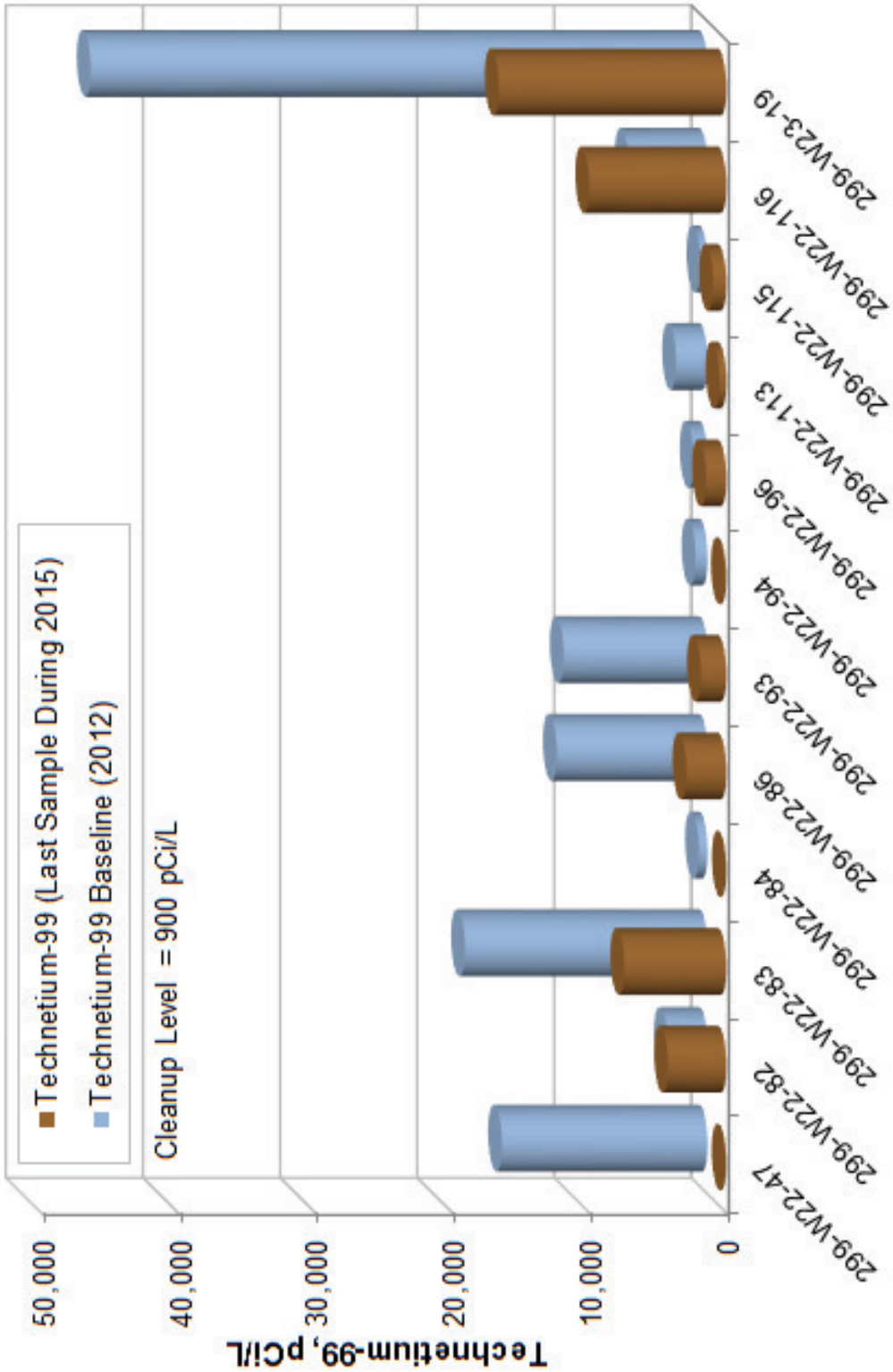


Figure 2-13. Comparison of 2015 Technetium-99 Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

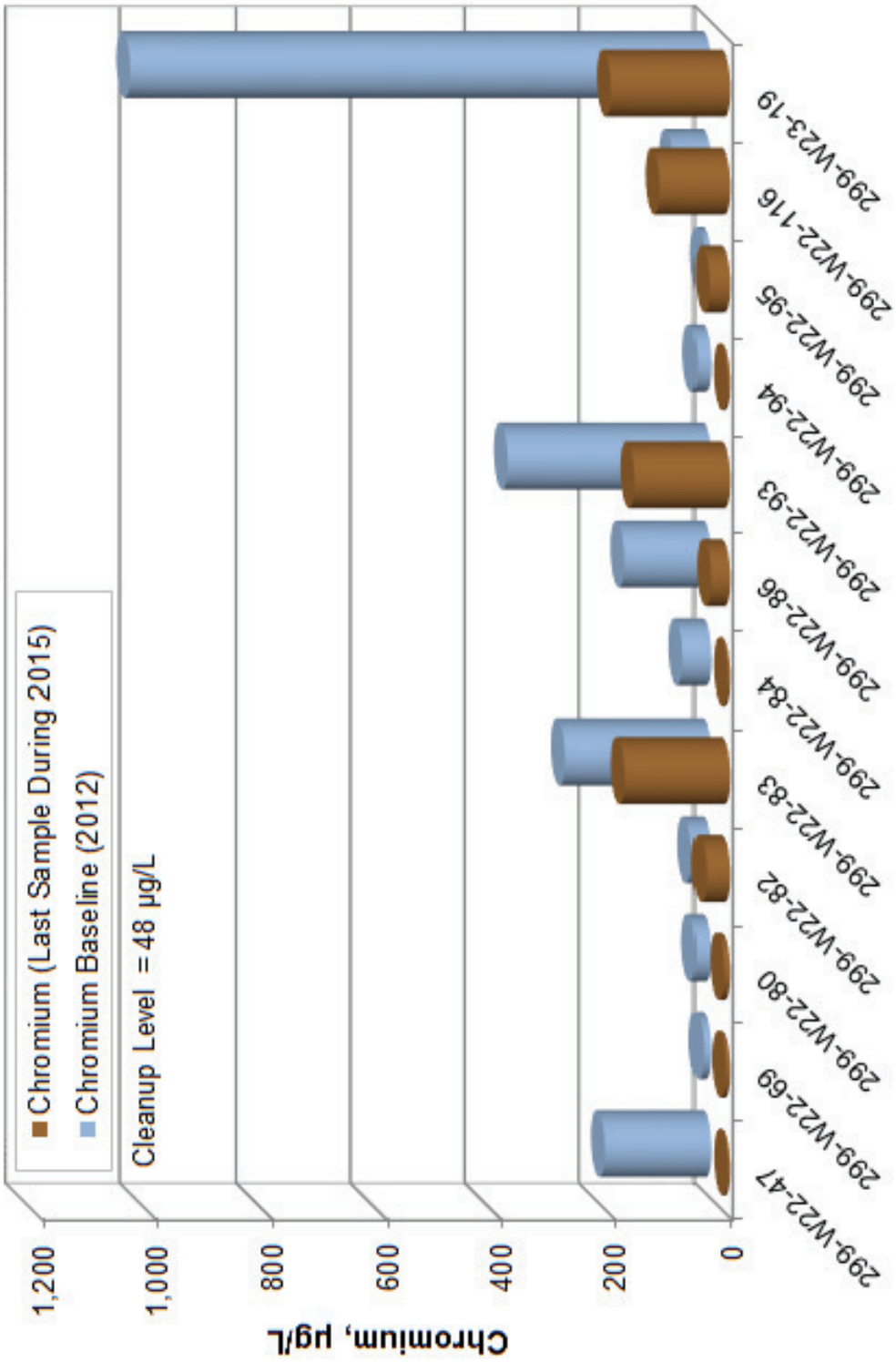


Figure 2-14. Comparison of 2015 Chromium Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

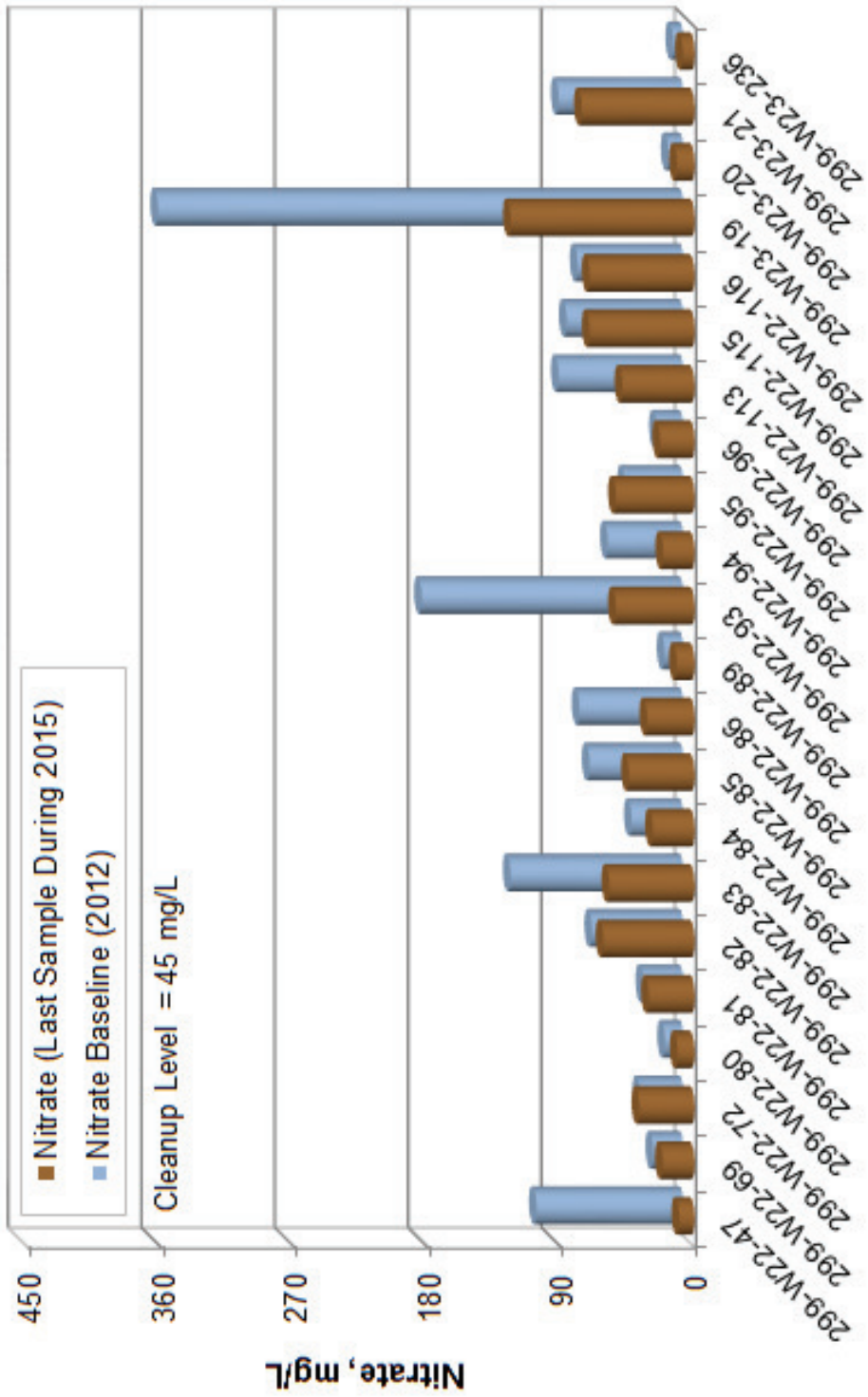


Figure 2-15. Comparison of 2015 Nitrate Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

Concentration changes have been substantial for many of the monitoring wells with a baseline concentration above a cleanup level. For the 6 wells with declining technetium-99 concentrations that had a baseline concentration above the cleanup level, all of the declines are greater than 50 percent (ranging from 58 to 100 percent [Table 2-5]). It should be noted that these 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 have increased by 47 percent in 299-W22-82 and 74 percent in 299-W22-116. These wells are located near 299-W22-91, which is pumping at an average rate of 130 L/min (34 gpm). The concentration increases in 299-W22-82 and 299-W22-116 indicate that water with high technetium-99 concentration is being drawn into the extraction well. As explained above, the technetium-99 concentration has increased to above the cleanup level at 299-W22-115 (84 percent increase over baseline).

Concentration changes for chromium are similar to technetium-99. For the 5 wells with declining chromium concentrations that had a baseline concentration above the cleanup level, 4 have declined by more than 50 percent (ranging from 54 to 98 percent [Table 2-6]). Concentrations have increased at 299-W22-116 by 88 percent (and have increased at 299-W22-82 by 26 percent, although this well had a baseline concentration below the cleanup level) for the same reason as technetium-99; water with high chromium concentration is being drawn into 299-W22-91.

The nitrate concentration decreases have not been as substantial. Although concentrations are declining in all 12 wells with a baseline concentration above the cleanup level, only half of these wells have declined by greater than 50 percent (Table 2-7). For all 12 wells, the concentration declines range from 1 to 90 percent. The lowest declines were in 299-W22-116 and 299-W22-82, both at 1 percent. The nitrate plume near the SX Tank Farm is wider than the technetium-99 and 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 chromium concentrations in the OU (Figure 2-16). The December 2015 sample results were 16,600 pCi/L for technetium-99 compared to a baseline of 45,000 pCi/L (63 percent decline), 205 µg/L for chromium compared to a baseline of 1,010 µg/L (80 percent decline), and 124 mg/L for nitrate compared to the baseline of 355 mg/L (65 percent decline). This well is located within the source area, and concentrations have varied in the well over time (Figure 2-16), which is presumed to have been 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 2015 is 62 m/yr (204 ft/yr) (DOE/RL-2016-09), 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.

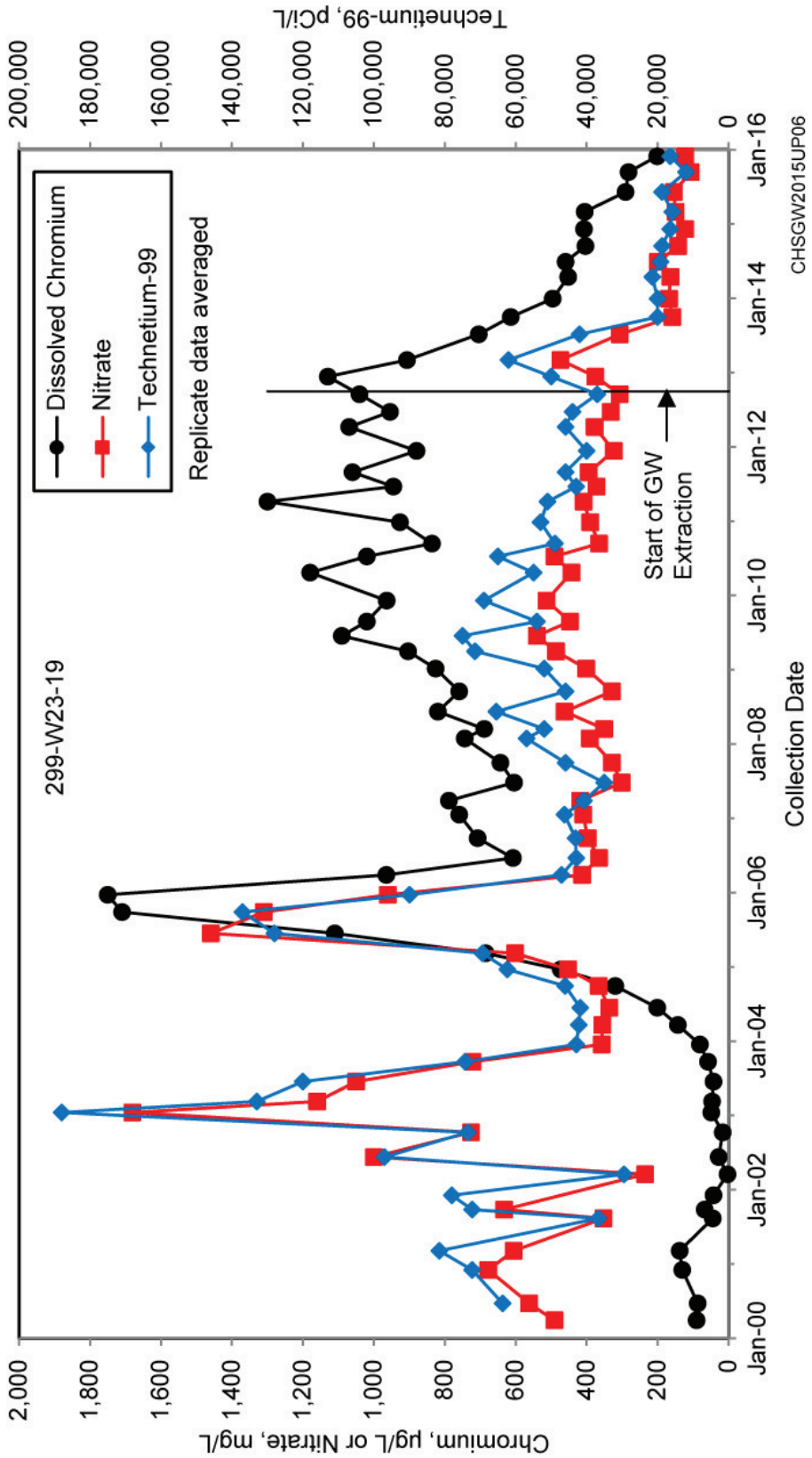


Figure 2-16. Technetium-99, Chromium, and Nitrate Concentrations in Well 299-W23-19 within the SX Tank Farm

Concentrations in the northern plume extraction well (299-W22-90) have declined since startup of pumping in 2012 (Figures 2-17, 2-18, and 2-19). The technetium-99 concentration has declined by 89 percent from 7,010 pCi/L in August 2012 to 756 pCi/L in October 2015, the chromium concentration has declined by 87 percent from 364 to 46 µg/L, and the nitrate concentration has declined by 76 percent from 113 to 27.4 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 was first sampled in December 2015. The results were 1,850 pCi/L for technetium-99, 164 µg/L for chromium, and 53.1 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. Nevertheless, concentrations in 299-W22-93 are substantially lower than the baseline sample results from 299-W22-44 (Tables 2-5, 2-6, and 2-7) indicating good progress in remediating the plumes.

Technetium-99, 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 2-17, 2-18, and 2-19). 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 (e.g., see Figures 2-7, 2-8, and 2-9). 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 declined to below the cleanup level in 299-W22-90 during 2015 (October 2015 sample result was 756 pCi/L). Chromium concentrations declined to below the 48 µg/L cleanup level in 299-W22-90 and 299-W22-92 during 2015 (October 2015 sample results were 46 and 41 µg/L, respectively).

2.2.3.2 Carbon Tetrachloride Monitoring Results

Carbon tetrachloride is widespread throughout the area surrounding the S and SX Tank Farms (Figure 2-20); in fact, this plume is widespread throughout the 200 West Area (see Figure 3-20 in Chapter 3). 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 (the U Pond received some waste streams from the PFP).

The 2015 carbon tetrachloride sample results from monitoring wells in the WMA S-SX vicinity are compared to baseline concentrations in Table 2-8 and Figure 2-21. Trends in carbon tetrachloride concentrations are mixed. For example, substantial declines have occurred in 299-W22-45 and 299-W22-86, while a substantial increase has occurred at 299-W22-113 (replacement for 299-W22-49) (Figure 2-22). The June 2015 sample result for 299-W22-45 was 12 µg/L compared to a baseline of 78 µg/L (85 percent decline), and the December 2015 sample result for 299-W22-86 was 18 µg/L compared to a baseline of 90.5 µg/L (80 percent decline). The concentration in 299-W22-113 was 97 µg/L in December 2015 compared to a baseline of 59 µg/L (64 percent increase).

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 2-23). Concentrations in wells 299-W22-91 and 299-W22-92 had been declining but were generally stable in 2015 (Figure 2-23). The maximum concentration during 2015 was 81 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.

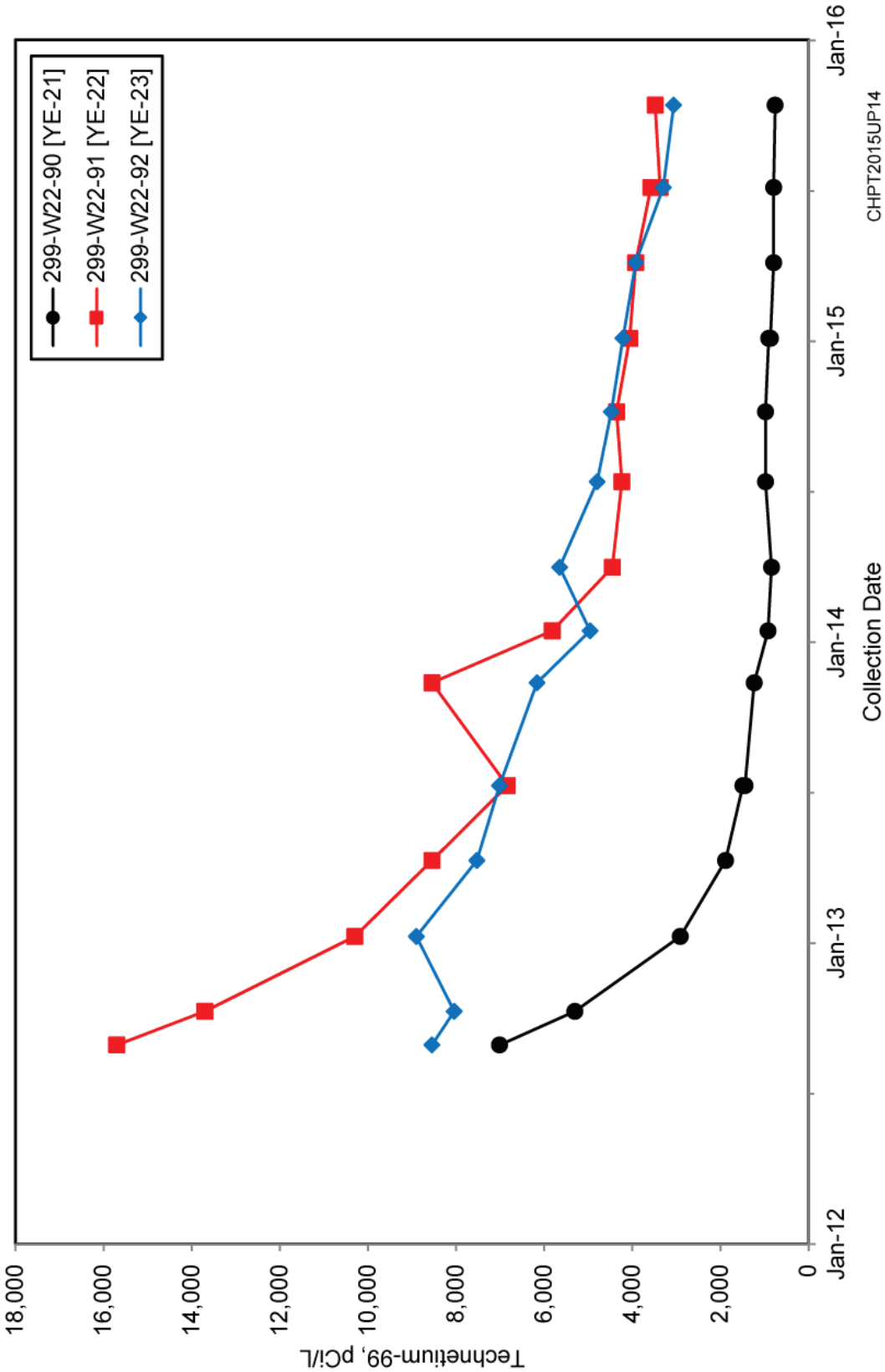


Figure 2-17. Technetium-99 Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

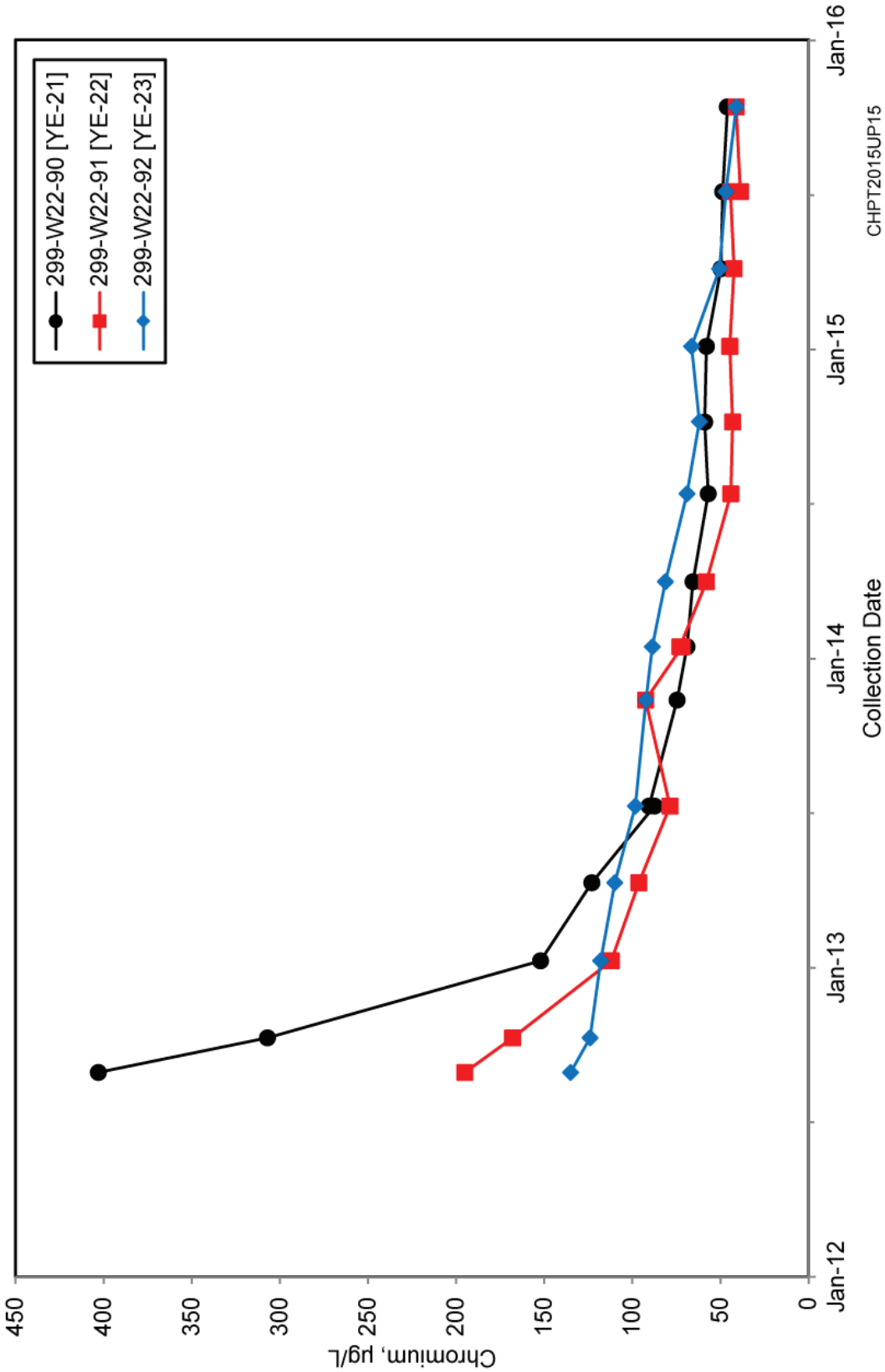


Figure 2-18. Chromium Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

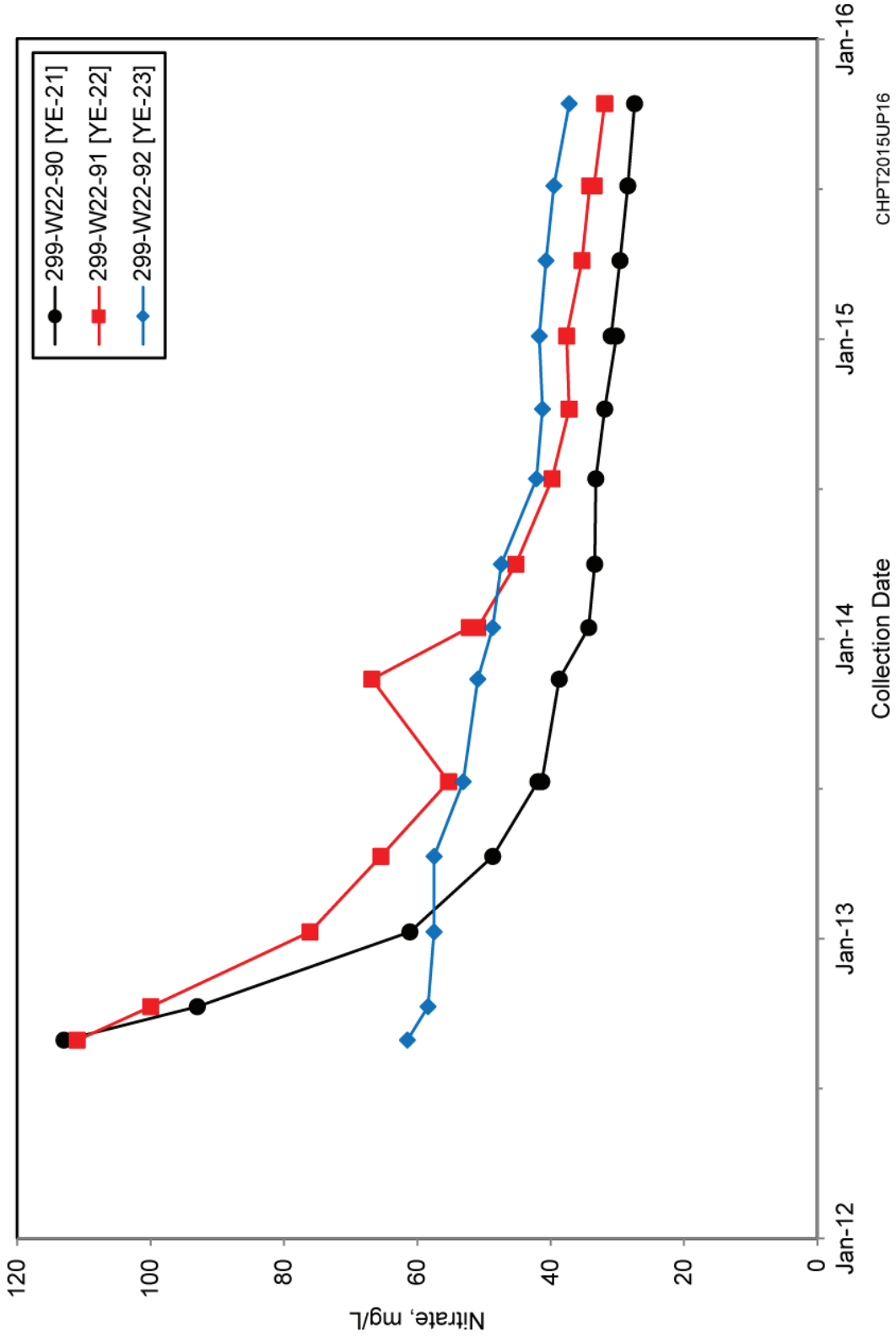


Figure 2-19. Nitrate Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

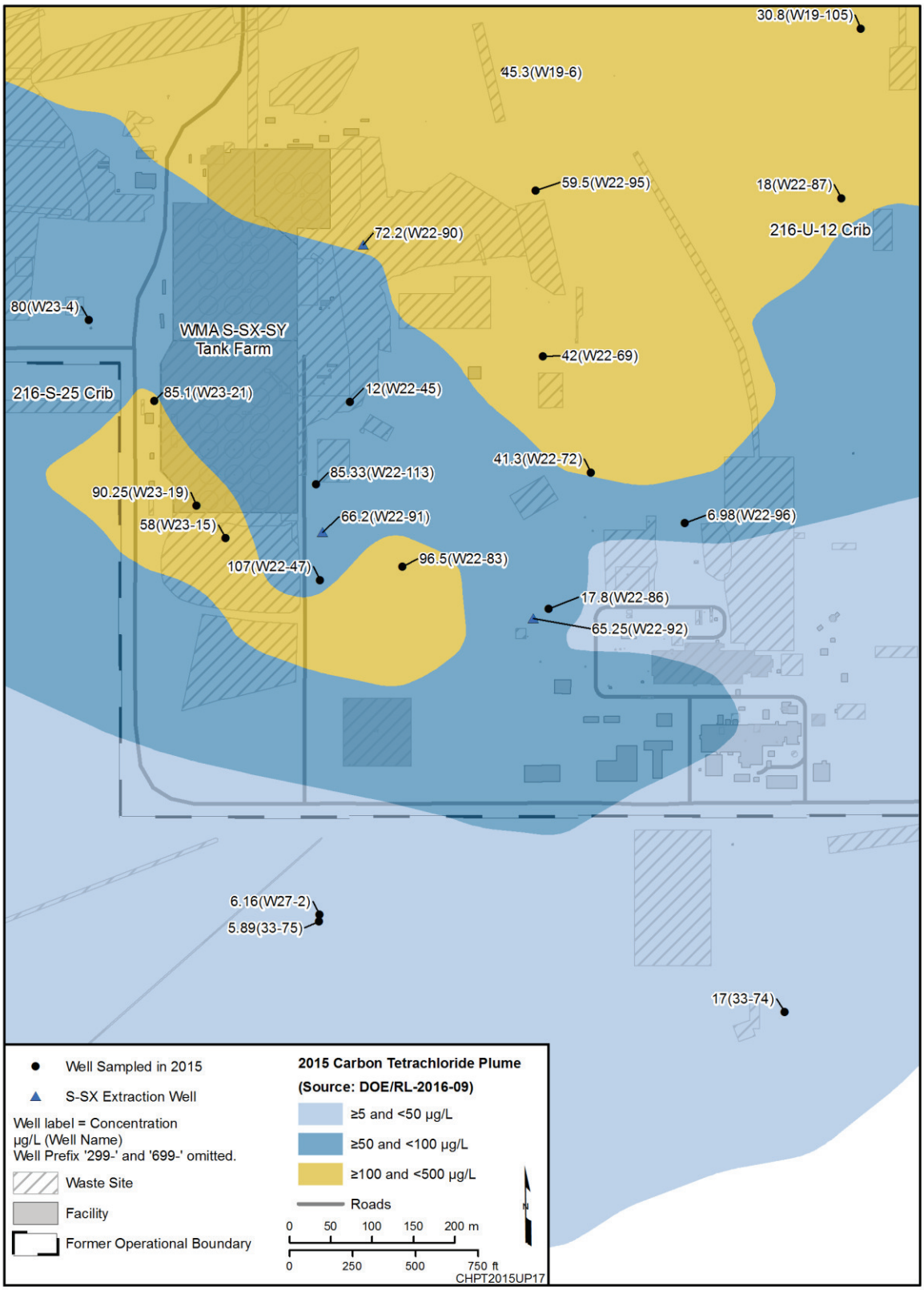


Figure 2-20. Carbon Tetrachloride Plume in Groundwater near the S-SX Tank Farms, 2015

Table 2-8. Comparison of 2015 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)	2015 Carbon Tetrachloride (µg/L)[a]	Difference (%)[b]
299-W22-45	78	12	-85
299-W22-47	105	107	+2
299-W22-69	24	42	+75
299-W22-72	23.8	41.3	+74
299-W22-80	Not sampled	Not sampled	—
299-W22-81	Not sampled	Not sampled	—
299-W22-82	Not sampled	Not sampled	—
299-W22-83	90	93	+3
299-W22-84	Not sampled	Not sampled	—
299-W22-85	Not sampled	Not sampled	—
299-W22-86	90.5	18	-80
299-W22-89	Not sampled	Not sampled	—
299-W22-93[c]	13[c]	Not sampled	—
299-W22-94[d]	1.20[d]	Not sampled	—
299-W22-95[e]	67[e]	61	-9
299-W22-96	4.4	6.98	+59
299-W22-113[f]	59[f]	97	+64
299-W22-116[g]	82[g]	Not sampled	—
299-W23-15	73.5	58	-21
299-W23-19	84	92.3	+10
299-W23-20	Not sampled	Not sampled	—
299-W23-21	113	85.1	-25

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 2015, the result shown is from the last sample of the year.

b. Differences shown are for only those wells with a baseline or 2015 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.

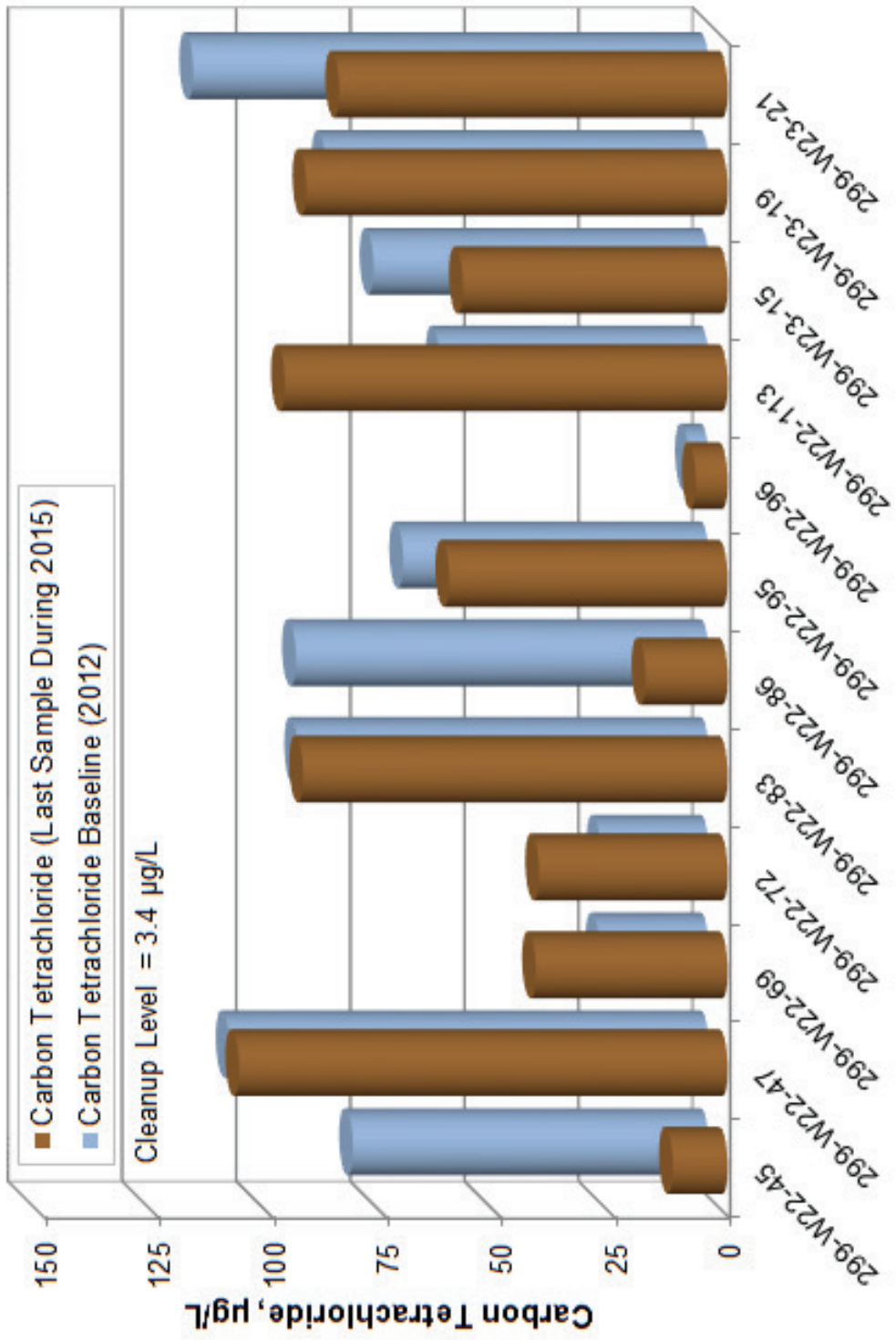


Figure 2-21. Comparison of 2015 Carbon Tetrachloride Sample Results for Selected Wells near the S-SX Tank Farms to Baseline Concentrations Prior to the Start of Groundwater Extraction

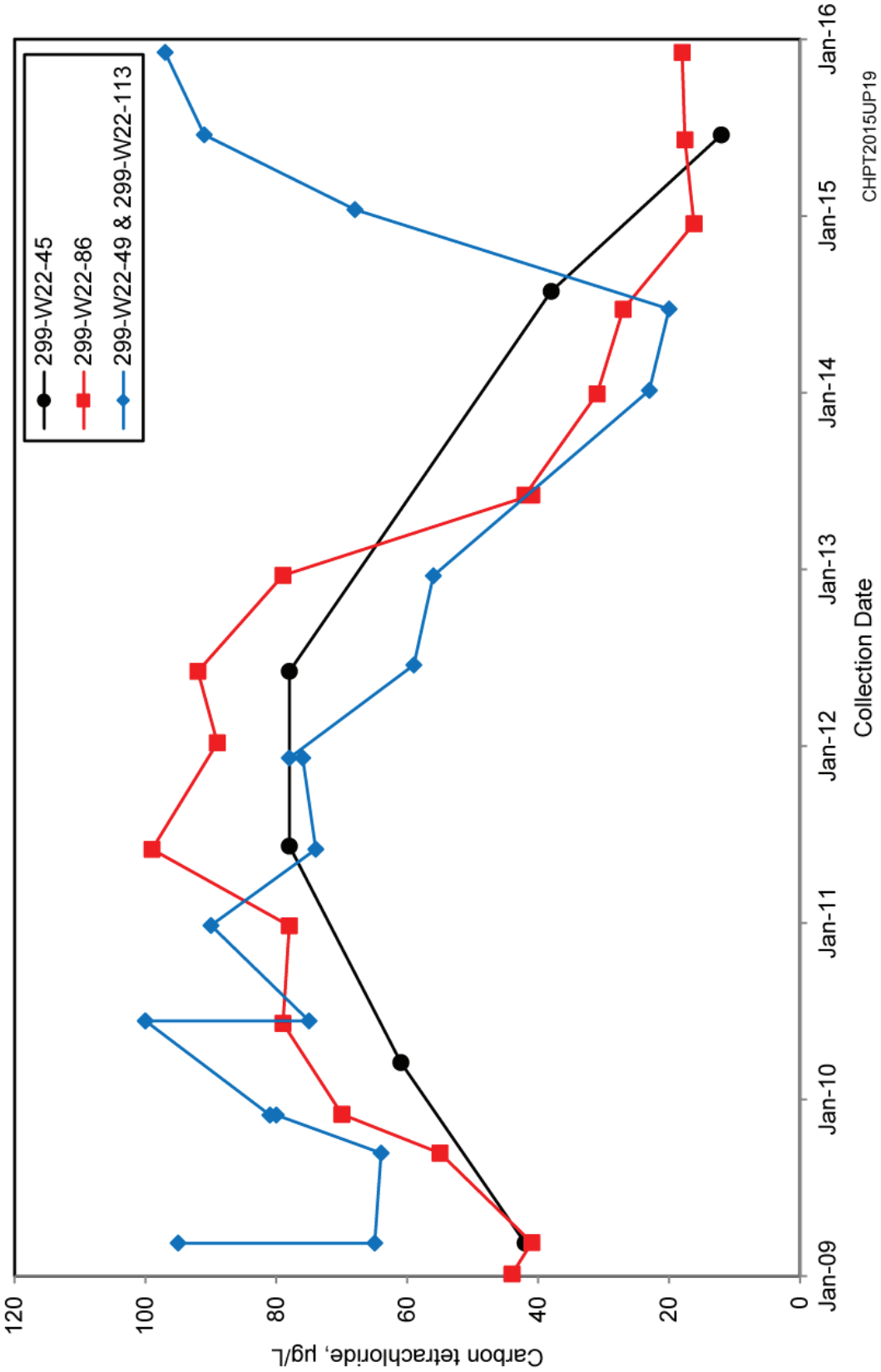


Figure 2-22. Carbon Tetrachloride Concentrations in Wells 299-W22-45, 299-W22-86, and 299-W22-113 (Replacement for 299-W22-49)

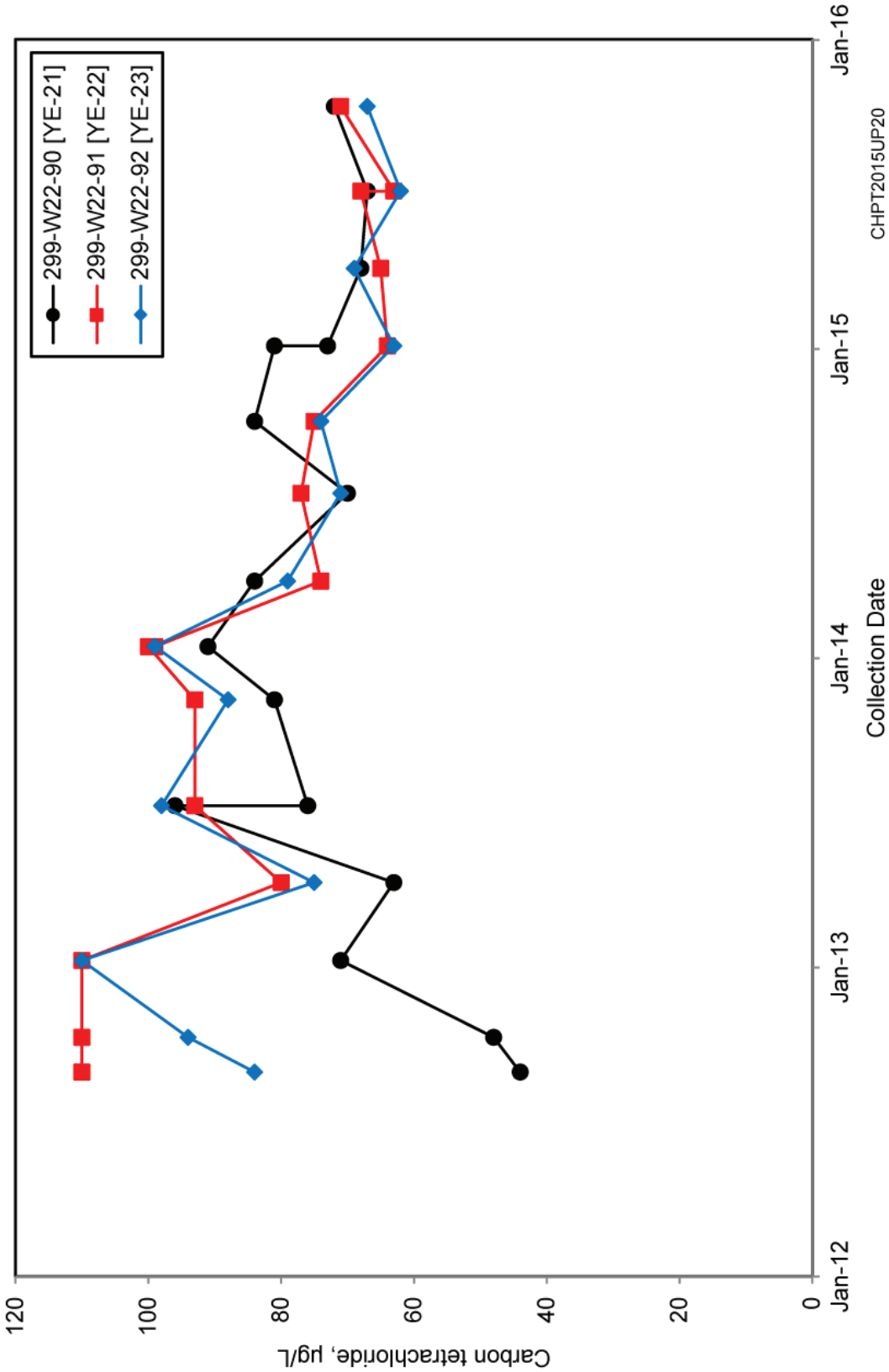


Figure 2-23. Carbon Tetrachloride Concentrations in WMA S-SX Extraction Wells after the Start of Groundwater Extraction

2.2.3.3 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 2015 are shown in Figure 2-24. 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 2015 value was 9,640 pCi/L indicating substantial progress in reducing the mean plume concentration.

2.3 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 which 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 2-25).

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). During 2015, construction of the P&T system was completed. The 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. Modifications to the radiological building to add an IX treatment train to remove uranium from the extracted water were also completed during 2015.

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.

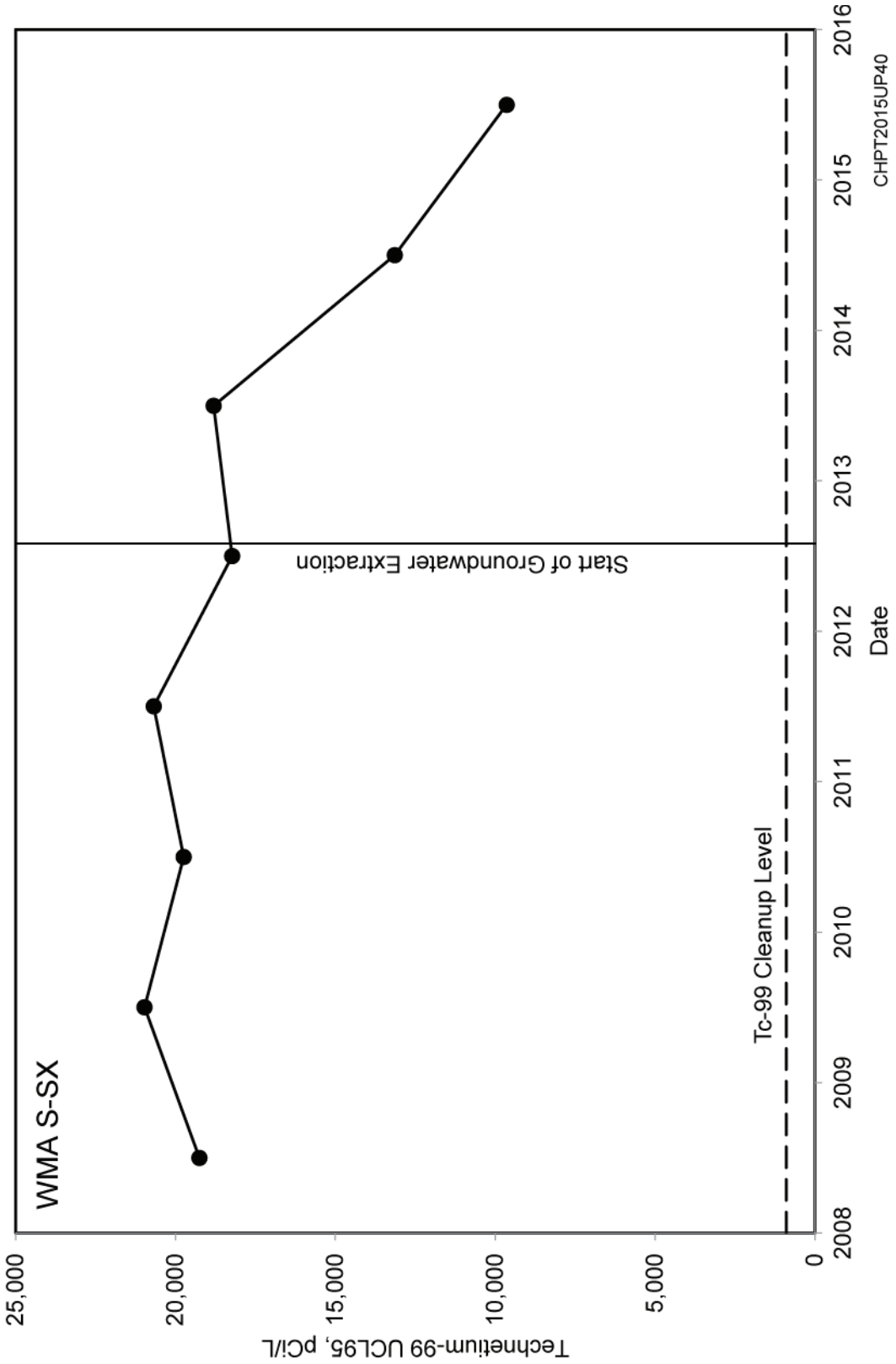


Figure 2-24. Upper Confidence Limits (95th Percentile) on the Mean Concentration of Technetium-99 for the WMA S-SX Groundwater Extraction System

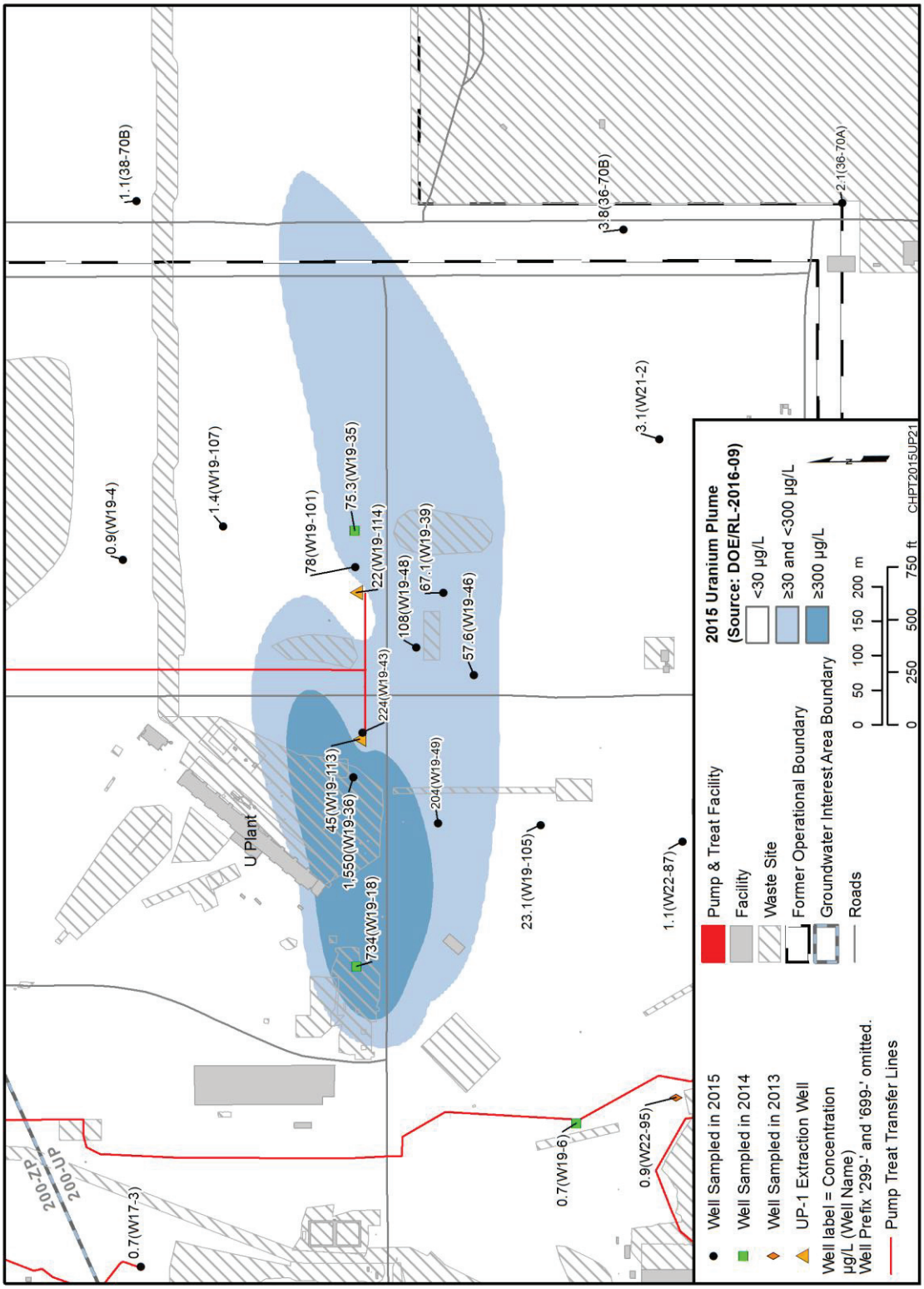


Figure 2-25. U Plant Area P&T System and the Uranium Plume, 2015

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 (200 East Area). The water from these wells then passes through the uranium IX treatment train. The water is then 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 radionuclide treatment) and passed through the central treatment process. The treated water is then returned to the aquifer using injection wells. The treatment system is further described in Section 3.1 in Chapter 3.

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 system 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 (approximately 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.

2.3.1 Remedial System Operation

The U Plant area P&T system operated greater than 90 percent of the time after beginning operations in September 2015. 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 2015 after operations began.

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.

2.3.1.1 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). The system was initially brought online at a lower flow rate (about 380 L/min [100 gpm]) and flow was slowly increased during the startup period. From startup through the end of the year, 299-W19-113 operated at an average rate of 143 L/min (38 gpm) and 299-W19-114 operated at an average rate of 325 L/min (86 gpm), yielding a combined average rate of 468 L/min (124 gpm) or 82 percent of the design capacity. Average flow rates of 157 L/min (41 gpm) for 299-W19-113 and 375 L/min (99 gpm) for 299-W19-114 were achieved during the last week of the year. This yielded a combined flow rate of 532 L/min (141 gpm) at year end[5]. The total volume of water extracted from the aquifer during 2015 was 65.4 million L (17.3 million gal). The lower-than-nominal flow rate during the startup period was caused by sand in the water pumped from 299-W19-113 which was clogging a filter in the system. This issue was resolved by raising the pump into a blank casing between sections of screen (the pump in this well had been installed near the bottom of the screen).

[5] The nominal combined flow rate of 568 L/min (150 gpm) was achieved during January 2016.

2.3.1.2 Extraction Well Mass Removal

The U Plant area P&T extraction wells are sampled quarterly, and were sampled during October after startup in September. The results of this sampling are provided in Table 2-9. 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 2-10.

Table 2-9. Extraction Well Sample Results for the U Plant Area P&T System

Well Name	Constituent	10/15/2015 Result
299-W19-113 (YE-25)	Carbon Tetrachloride (µg/L)	91
	Nitrate (mg/L as NO_3)	930
	Technetium-99 (pCi/L)	8,610
	Uranium (µg/L)	45
299-W19-114 (YE-26)	Carbon Tetrachloride (µg/L)	72
	Nitrate (mg/L as NO_3)	181
	Technetium-99 (pCi/L)	980
	Uranium (µg/L)	22

Table 2-10. Contaminant Mass (or Activity) Removed from the Aquifer by the U Plant Area P&T System

Constituent	Mass (Activity) Removed during 2015
Carbon Tetrachloride, kg	5.3
Nitrate (as NO_3), kg	22,300
Technetium-99, g (Ci)	11.0 (0.19)
Uranium, kg	1.8

2.3.1.3 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. Section 3.1 in Chapter 3 provides a description of the treatment system and its performance during 2015. The uranium and technetium-99 removal efficiencies for the entire system during 2015 averaged 97 and 95 percent, respectively, and the nitrate removal efficiency averaged 78 percent (Table 3-2 in Chapter 3). 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) (Table 3-5 in Chapter 3).

2.3.2 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 2015.

2.3.2.1 Water Level Measurements

During 2015, synoptic manual depth-to-water measurements were collected monthly beginning in July from monitoring wells near the U Plant P&T 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 2-2). 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.

2.3.2.2 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 2-26. This map depicts background water table conditions prior to startup of the U Plant area P&T system in September. Groundwater flow within this area is toward the northeast due to drawdown of the water table by the 200-ZP-1 P&T system. This map compares well with the larger OU water table map (Figure 2-4), indicating that the universal kriging technique is providing a reasonable depiction of the water table in the U Plant vicinity.

Figure 2-27 depicts the water table estimated capture zone for December 2015, as well as the uranium plume in groundwater. The capture zone was estimated by (1) mapping the groundwater elevation data for December using MEUK, and (2) 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 2015 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 2015 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 2-27 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 percent of the areal extent of the uranium plume above 30 µg/L and about 70 percent of the plume above 300 µg/L. Concentrations in the portions not being captured are predicted to decline to below the cleanup level by natural attenuation (DOE/RL-2009-122). This conclusion is based on results of the fate and transport modeling performed for the RI and FS. Modeling performed to evaluate the U Plant area P&T system indicated that the mean plume concentration (as determined by the UCL_{95}) would decline to below the cleanup level within 25 years after the start of the active remedy (Figure 6-21 in Appendix D of DOE/RL-2009-122). Additional wells will be installed beginning in 2016 to monitor this plume, and three of the wells will be designed as dual use monitoring/extraction wells. 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 2-28 and 2-29 show the December 2015 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, the entire high-concentration portion of the plume (i.e., greater than 450 mg/L) is within the capture zones. The selected remedies for nitrate were P&T for this high-concentration area at U Plant and MNA for the remainder of the plume. The capture zones indicate that the system will effectively capture this high-concentration region.

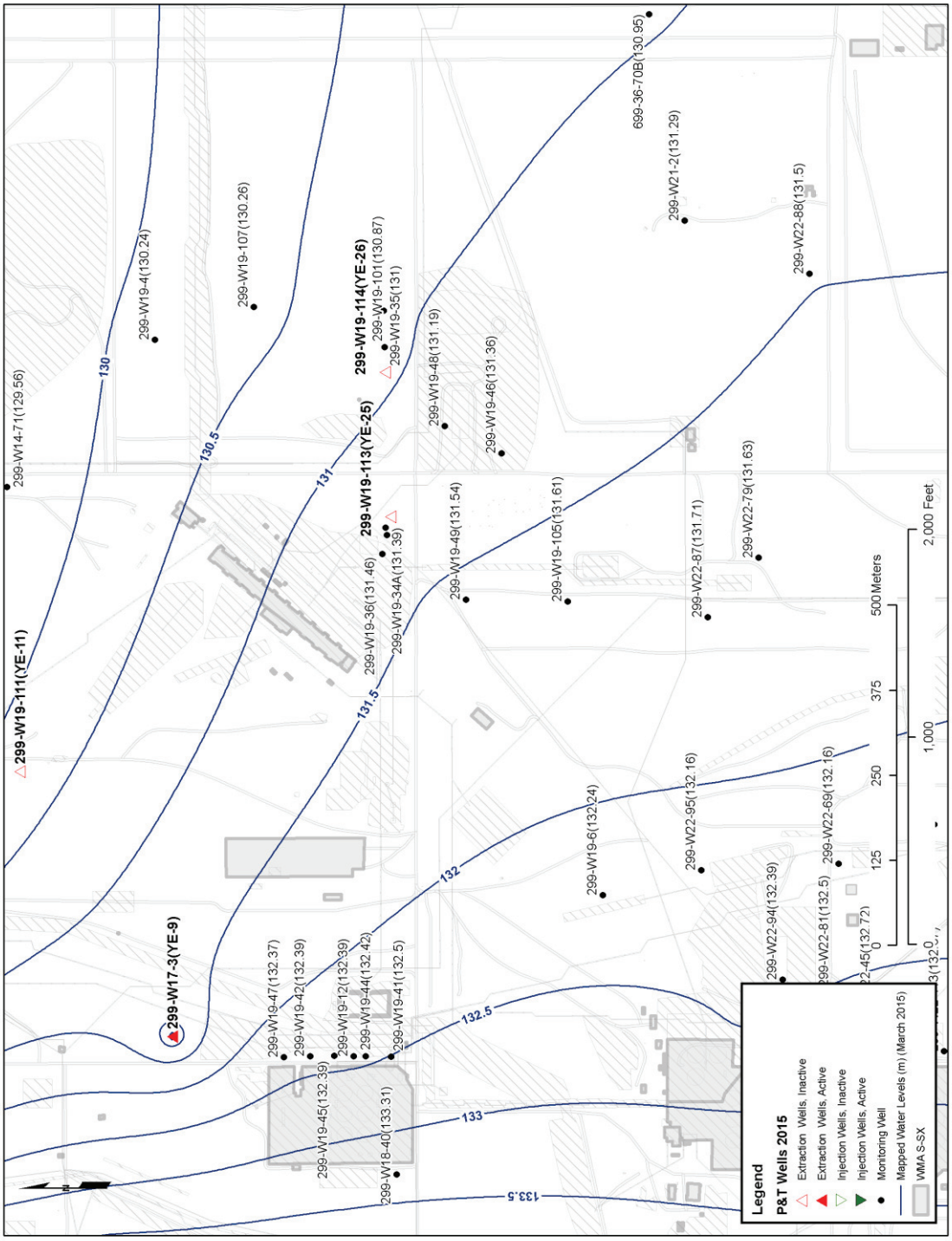


Figure 2-26. Baseline Water Table for the U Plant Area, March 2015

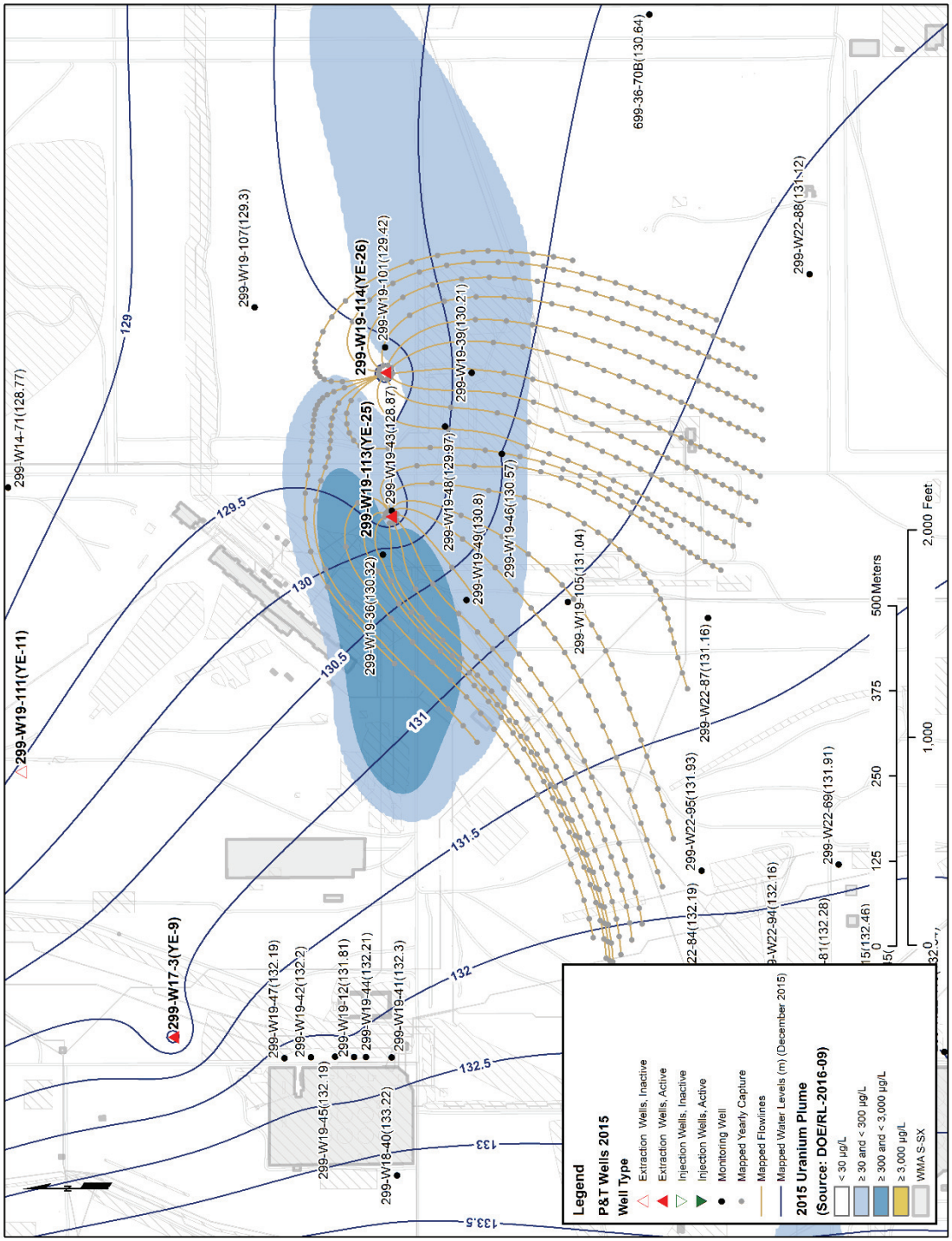


Figure 2-27. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area P&T System under December 2015 Conditions (Steady-State Assumption) Compared to the Uranium Plume

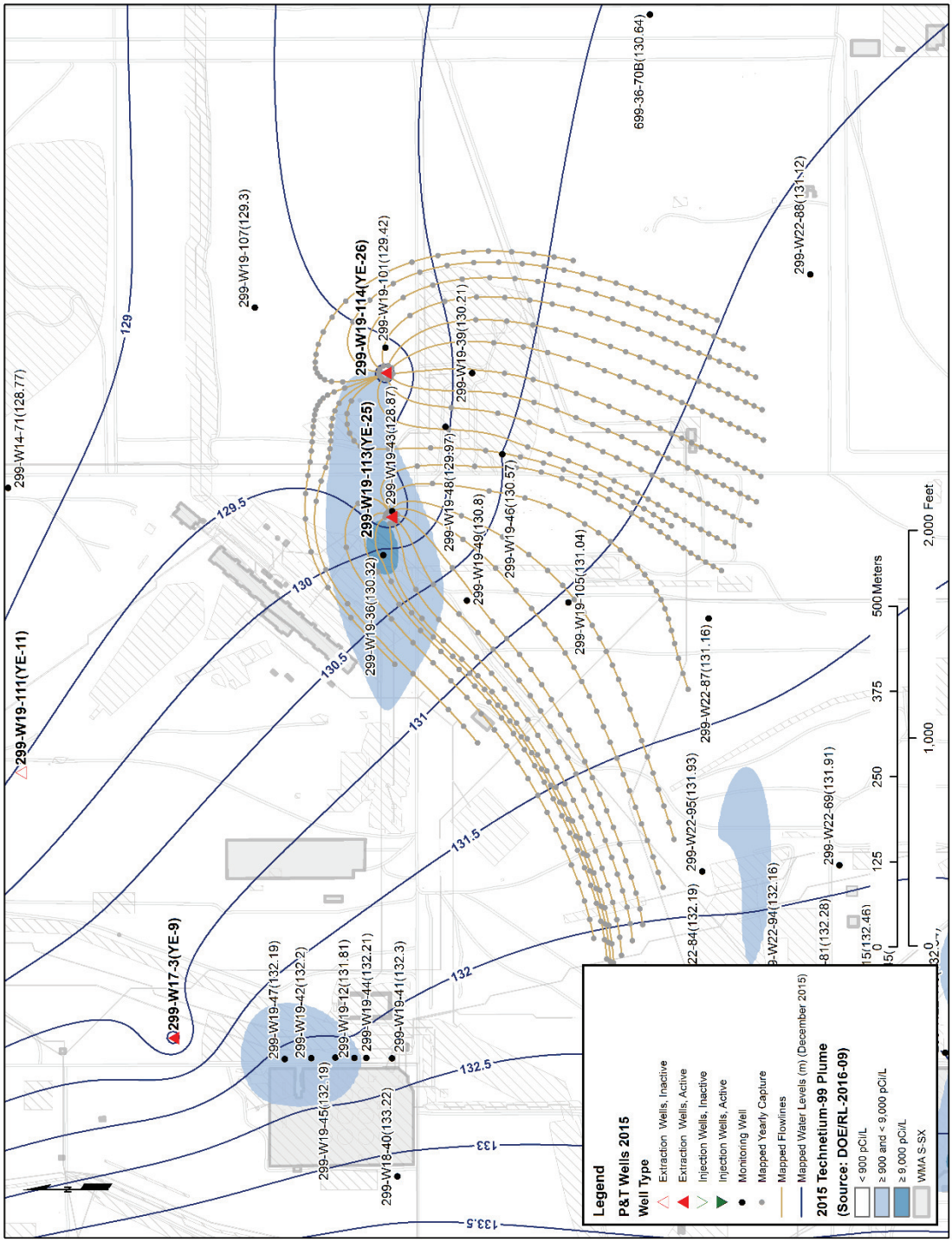


Figure 2-28. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area P&T System under December 2015 Conditions (Steady-State Assumption) Compared to the Technetium-99 Plume

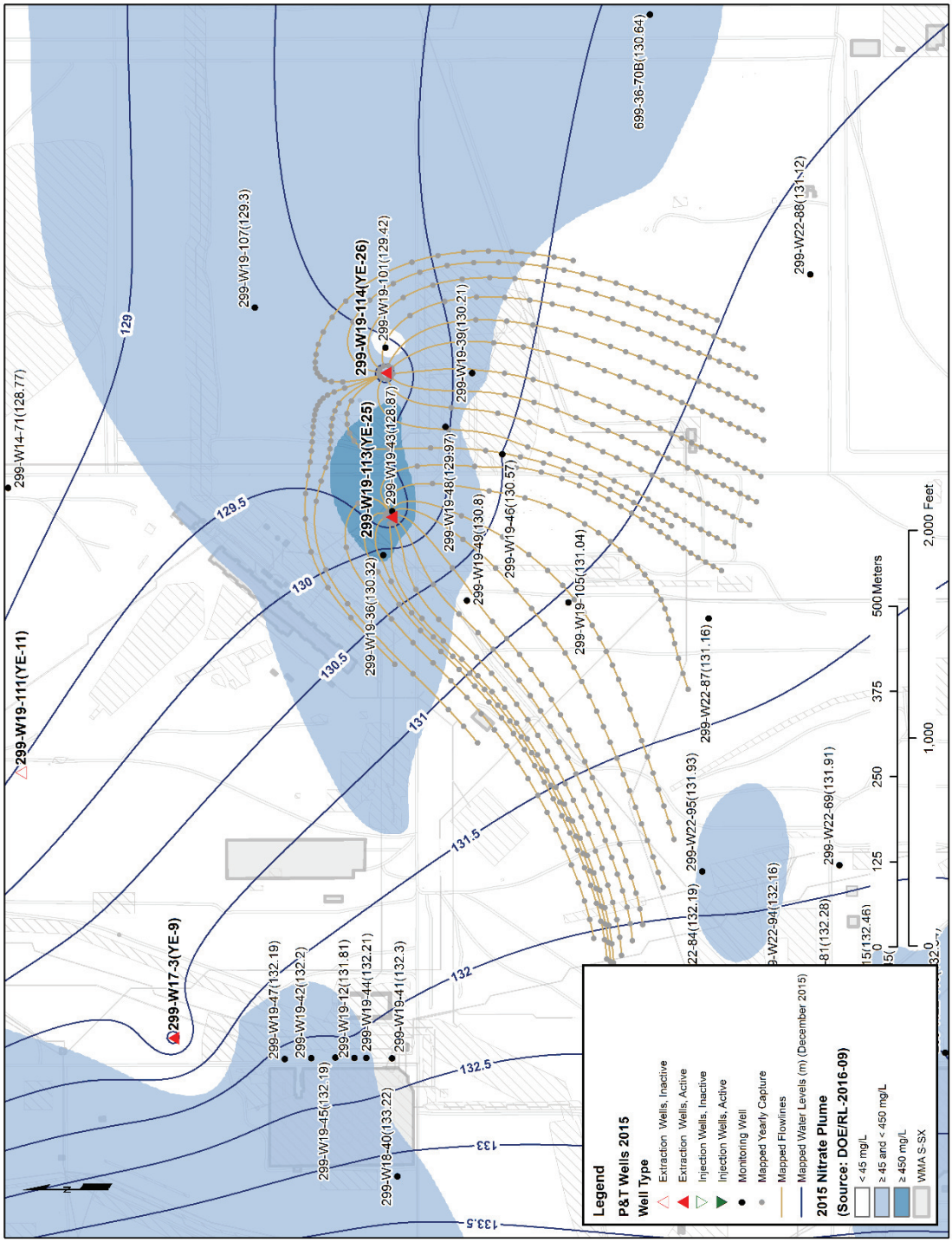


Figure 2-29. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area P&T System under December 2015 Conditions (Steady-State Assumption) Compared to the Nitrate Plume

The capture zones developed by 299-W19-113 and 299-W19-114, along with the capture zones predicted by model simulations when the system was designed, are depicted in Figure 2-30. There is very good agreement between the mapped and predicted capture zones. The mapped capture zones are slightly narrower than the simulated capture zones. This may be due to the system operating for only 3 months, with extraction rates during the startup period lower than the nominal 568 L/min (150 gpm), so the full capture zone has not yet developed. Overall, this comparison indicates that the system should function as intended.

2.3.3 Contaminant Monitoring

Since the U Plant area P&T system only operated during the last quarter of the year, most groundwater sample results from 2015 were used to establish baseline concentrations from which future remediation progress will be evaluated. Baseline sample results for the monitoring wells are listed in Table 2-11.

Table 2-11. Baseline Sample Results from Monitoring Wells in the U Plant Area

Monitoring Well	Uranium (µg/L)	Technetium-99 (pCi/L)	Nitrate (mg/L as NO_3)	Carbon Tetrachloride (µg/L)
299-W19-18	734	580	58.4	10
299-W19-34A	1.44	483	34.0	91.6
299-W19-34B	Not Analyzed	Not Analyzed	Not Analyzed	135
299-W19-36	1,550	51,400	788	9.9
299-W19-39	65	116	66.4	68.8
299-W19-4	0.877	15.9	165	48
299-W19-43	223	8,080	3,190	30.7
299-W19-46	63.3	94.5	29.9	12
299-W19-48	102	139	57.5	35
299-W19-49	223	304	38.6	136
299-W19-101	78	234	29.7	13
299-W19-105	25.7	20.4	10.6	27.3
299-W19-107	1.35	273	112	82

2.3.3.1 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 2-25). The highest concentrations occur at 299-W19-36, which had a uranium result of 1,550 µg/L during July 2015 (Figure 2-31). This is a substantial increase from the previous result of 185 µg/L during August 2014. The next highest concentrations occur at 299-W19-18, located about 90 m (300 ft) downgradient from the cribs. The latest reliable uranium sample result from this well was 734 µg/L in April 2014 (the 2015 sample result was deemed not representative because the well was nearly dry and could not be adequately purged) (Figure 2-31). A replacement well for 299-W19-18 will be drilled in 2016. Concentrations in other wells in the U Plant vicinity range from background levels up to 223 µg/L (299-W19-43 and 299-W19-49 in Table 2-11).

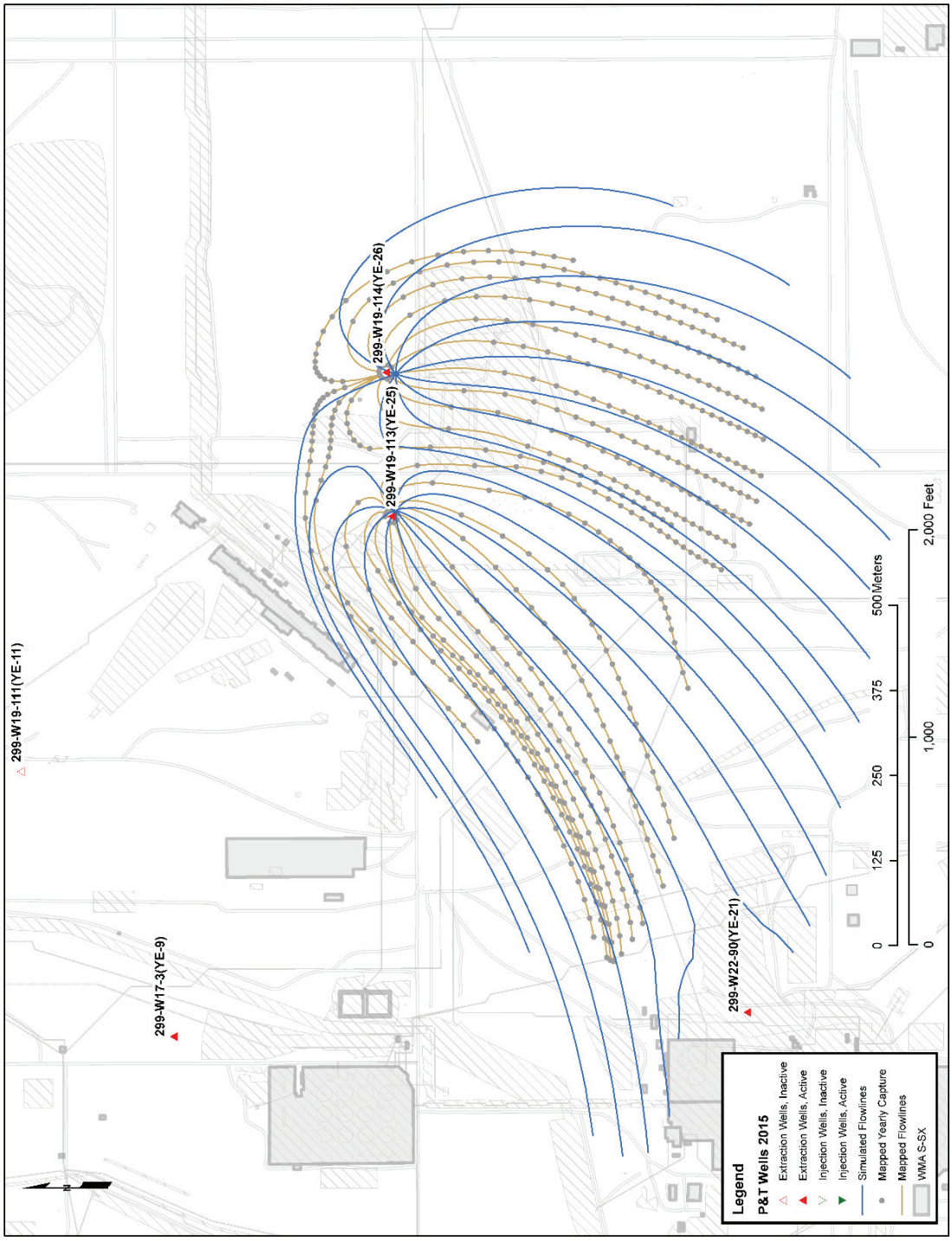


Figure 2-30. Comparison of Hydraulic Capture for the U Plant Area P&T System under December 2015 Conditions (Steady-State Assumption) to the Design Capture Zone

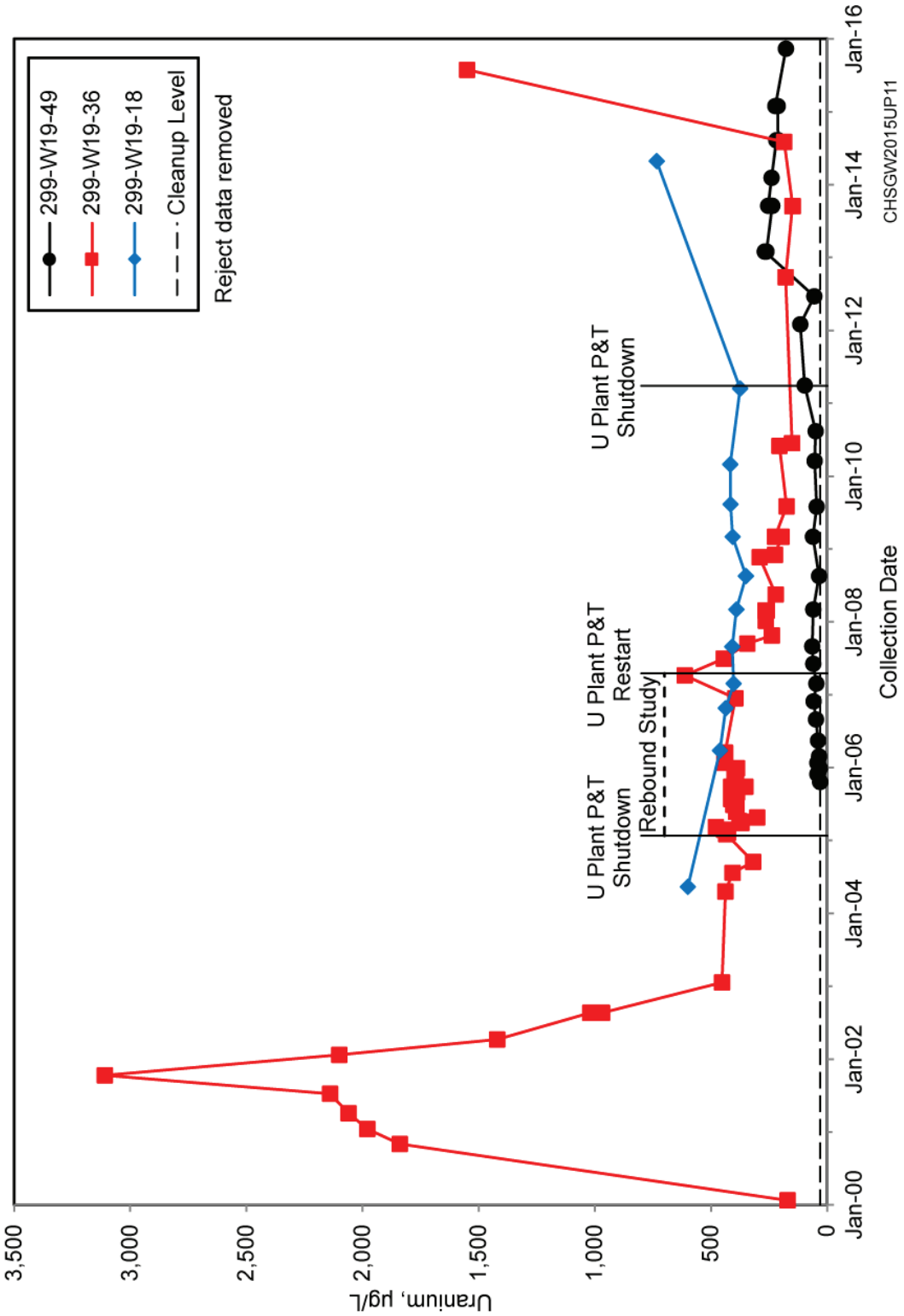


Figure 2-31. Uranium Concentrations in Selected Wells Downgradient from the 216-U-1 and 216-U-2 Cribs

With the exception of 299-W19-36 and 299-W19-43, concentration trends within the plume have been declining in recent years (Figure 2-32). The concentration at 299-W19-49 increased greatly from 55.6 µg/L in June 2012 to 268 µg/L in January 2013, but it has been declining since (to 177 µg/L in November 2015). The concentration increase in this well may have been due to the groundwater flow direction change caused by startup of the 200-ZP-1 P&T system. Concentrations have been generally stable at 299-W19-43 (Figure 2-32), and the concentration increased substantially at 299-W19-36 in 2015 as described in the preceding paragraph (Figure 2-31).

Depth-discrete sampling during drilling indicates that the uranium plume occurs within the upper 20 m (66 ft) of the aquifer. Results of sampling during drilling of the extraction wells (299-W19-113 and 299-W19-114) are shown in Table 2-12. Uranium was found in the uppermost sample from 299-W19-114 at 62.9 µg/L (4.3 m [14 ft] below the water table) but was 4.7 µg/L at 8.5 m (28 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-W19-113, the highest uranium result during drilling was 7.8 µg/L in the uppermost sample, but this result 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. Well 299-W19-113 was drilled by the cable tool method, whereas 299-W19-114 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-W19-113 even though this well was installed near the center of the uranium plume. Samples collected after the wells began operating showed 45 µg/L for 299-W19-113 and 22 µg/L for 299-W19-114 (Table 2-9). The higher concentration at 299-W19-113 is further indication that the uranium sample results during drilling were not representative of aquifer conditions. The lower concentration at 299-W19-114 after well completion is caused by concentration averaging (i.e., the well is screened over a depth interval larger than the thickness of the uranium plume).

Table 2-12. Depth Profile Sample Results for the Uranium Plume Extraction 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-W19-113	13.9	32	1,250	4,780	7.8*
	32.5	160	633	1,010	2.5*
	52.2	26	166	48.7	0.84*
	72.5	120	27	312	1.0*
299-W19-114	14.0	4.2	68.2	110	62.9
	28.5	55	660	4,650	4.7
	48.5	43	549	3,010	2.6
	68.9	34	677	5,030	3.7
	89.2	76	203	1,270	1.5
	117.8	130	30.5	223	0.92

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

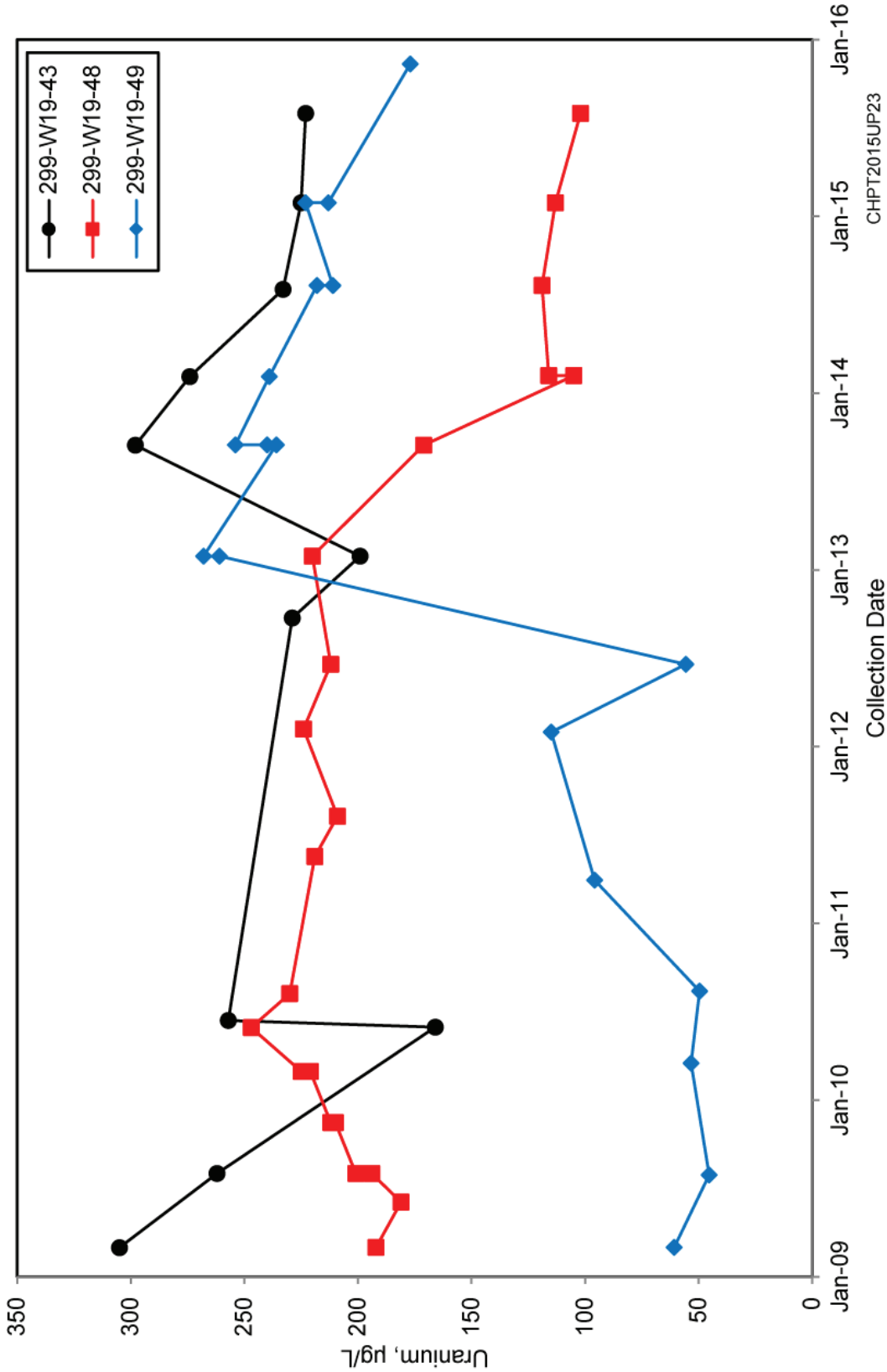


Figure 2-32. Uranium Concentrations in Selected Wells at the U Plant Area P&T System

2.3.3.2 Technetium-99 and Nitrate Monitoring Results

The technetium-99 and nitrate plumes in the U Plant area are shown in Figures 2-33 and 2-34, respectively. Technetium-99 concentrations exceed the 900 pCi/L cleanup level only in the former extraction wells of the interim action system, 299-W19-36 and 299-W19-43, and the extraction wells for the new P&T system, 299-W19-113 and 299-W19-114 (Figures 2-33 and 2-35). The baseline concentrations in 299-W19-36 and 299-W19-43 are 51,400 and 8,080 pCi/L, respectively (Table 2-11). The concentration increased substantially in 299-W19-36 from 21,000 pCi/L in September 2013 to 86,500 pCi/L in August 2014, but concentrations have since been declining. The concentration in 299-W19-43 has been trending upward since 2011. 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.

Similar to technetium-99, the highest baseline nitrate concentrations in the U Plant area occur at the former extraction wells: 299-W19-36 and 299-W19-43 (Figure 2-36). Baseline concentrations in these wells were 788 and 3,190 mg/L, respectively. Baseline concentrations exceed the 45 mg/L cleanup level in five other wells in the U Plant area ranging from 57.5 to 165 mg/L (Table 2-11).

2.3.3.3 Carbon Tetrachloride Monitoring Results

As explained in Section 2.2.3.2 for WMA S-SX, carbon tetrachloride is widespread throughout the 200 West Area (Figure 2-37). Baseline carbon tetrachloride concentrations exceed the 3.4 µg/L cleanup level in all wells in the U Plant area (Table 2-11). Concentrations range from 9.9 µg/L in 299-W19-36 to 136 µg/L in 299-W19-49. Concentrations generally increase with depth. Three of the four wells with the highest baseline concentrations are screened below the water table (299-W19-34A, 299-W19-34B, and 299-W19-107).

2.3.3.4 Performance Monitoring Calculations

Progress toward achieving cleanup levels for the U Plant 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 2015. 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 2015 are shown in Figure 2-38 for uranium and Figure 2-39 for technetium-99 and nitrate. The UCL_{95} values range between 160 and 320 µg/L for uranium; 1,710 and 16,500 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 2015 UCL_{95} values are 320 µg/L for uranium; 16,500 for technetium-99; and 1,100 for nitrate.

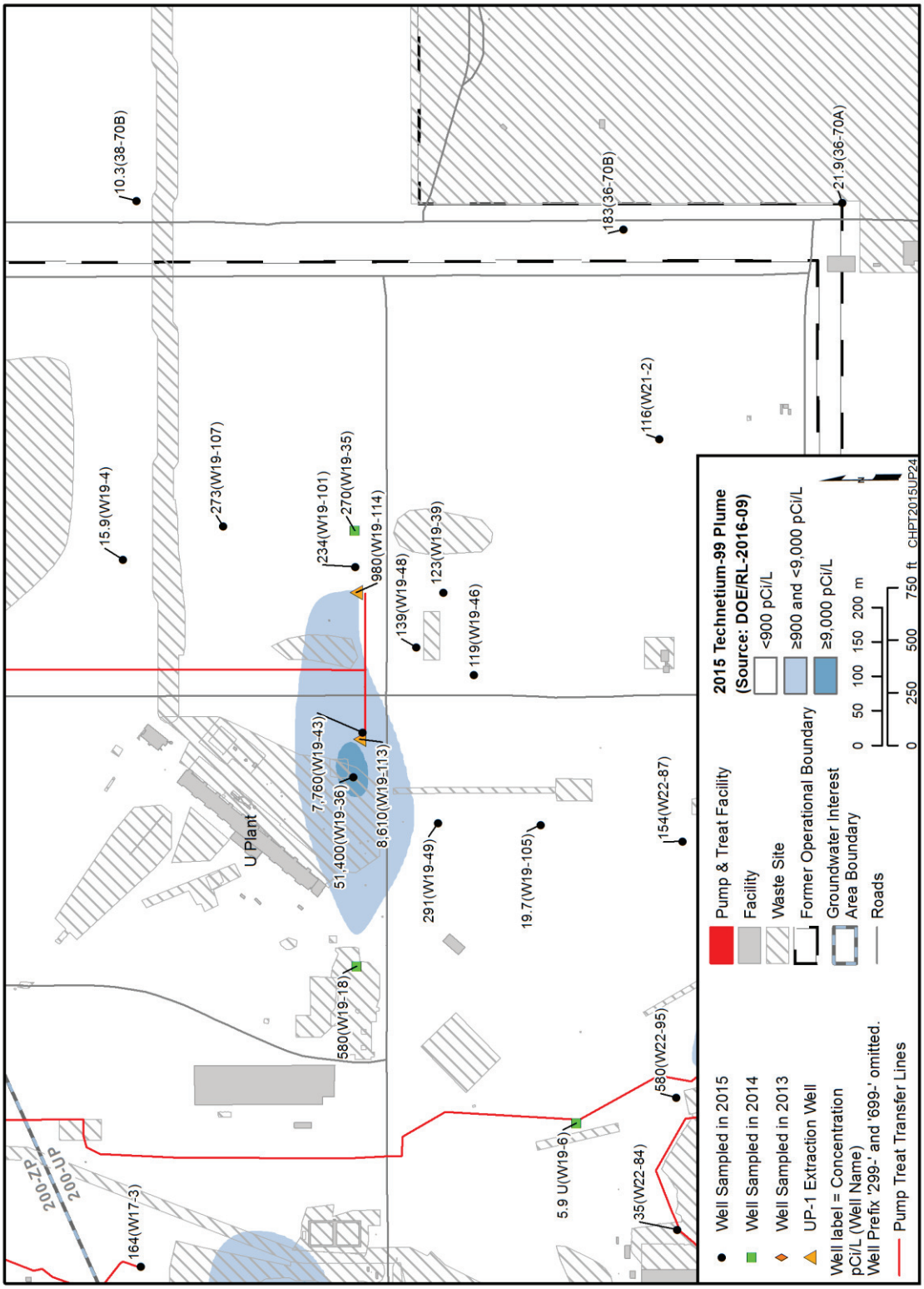


Figure 2-33. U Plant Area Technetium-99 Plume, 2015

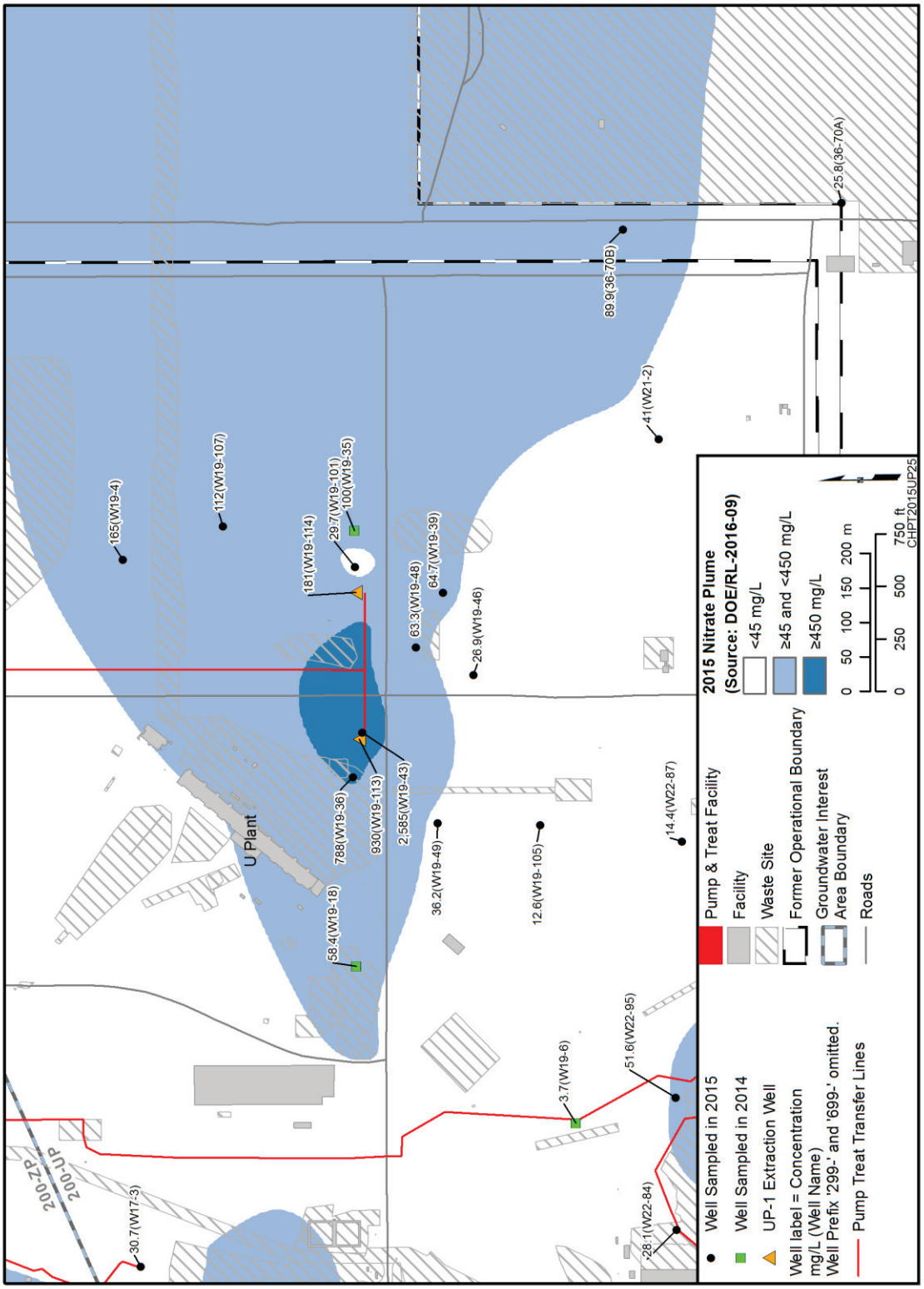


Figure 2-34. U Plant Area Nitrate Plume, 2015

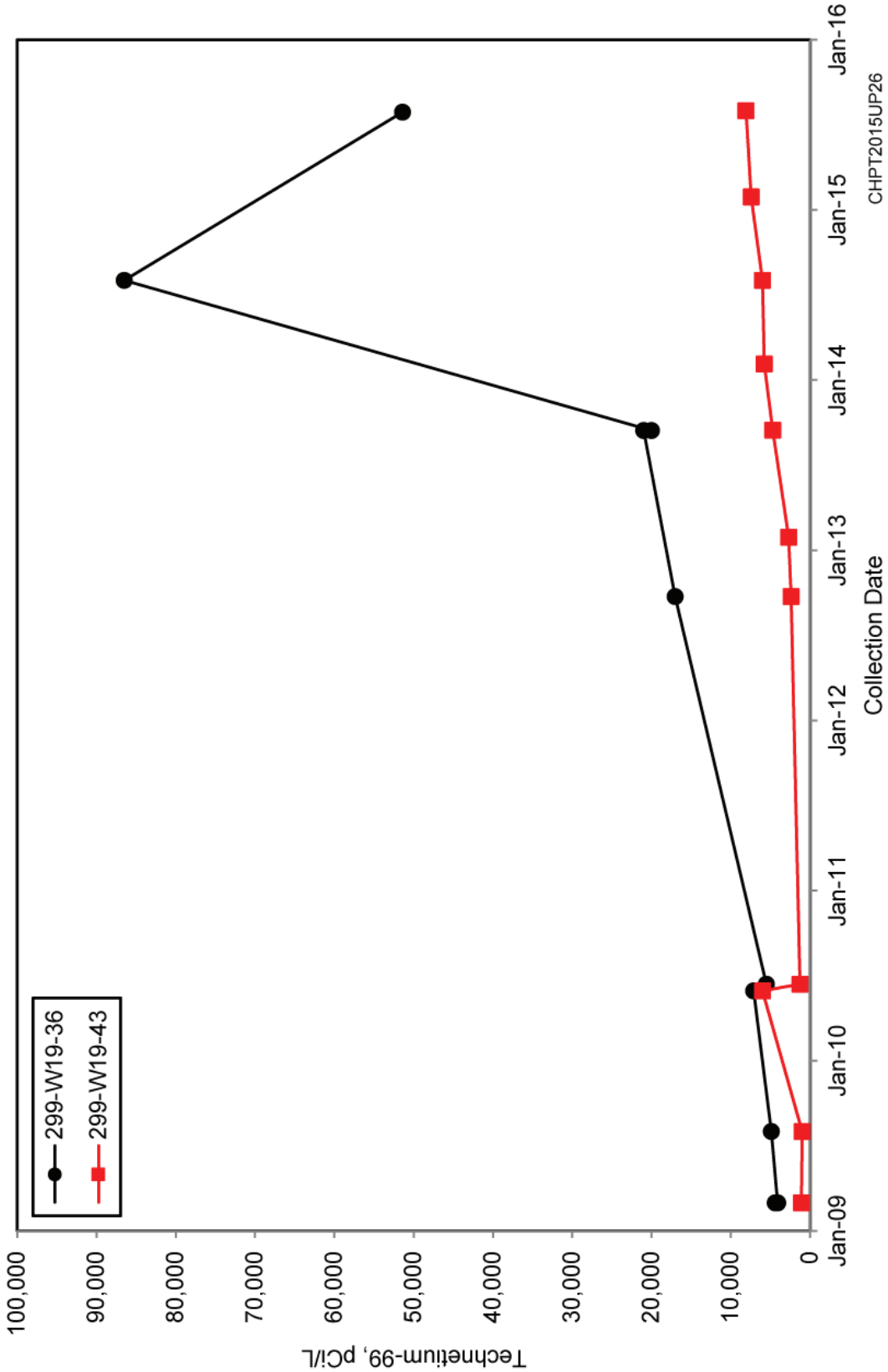


Figure 2-35. Technetium-99 Concentrations in Selected Wells at the U Plant Area P&T System

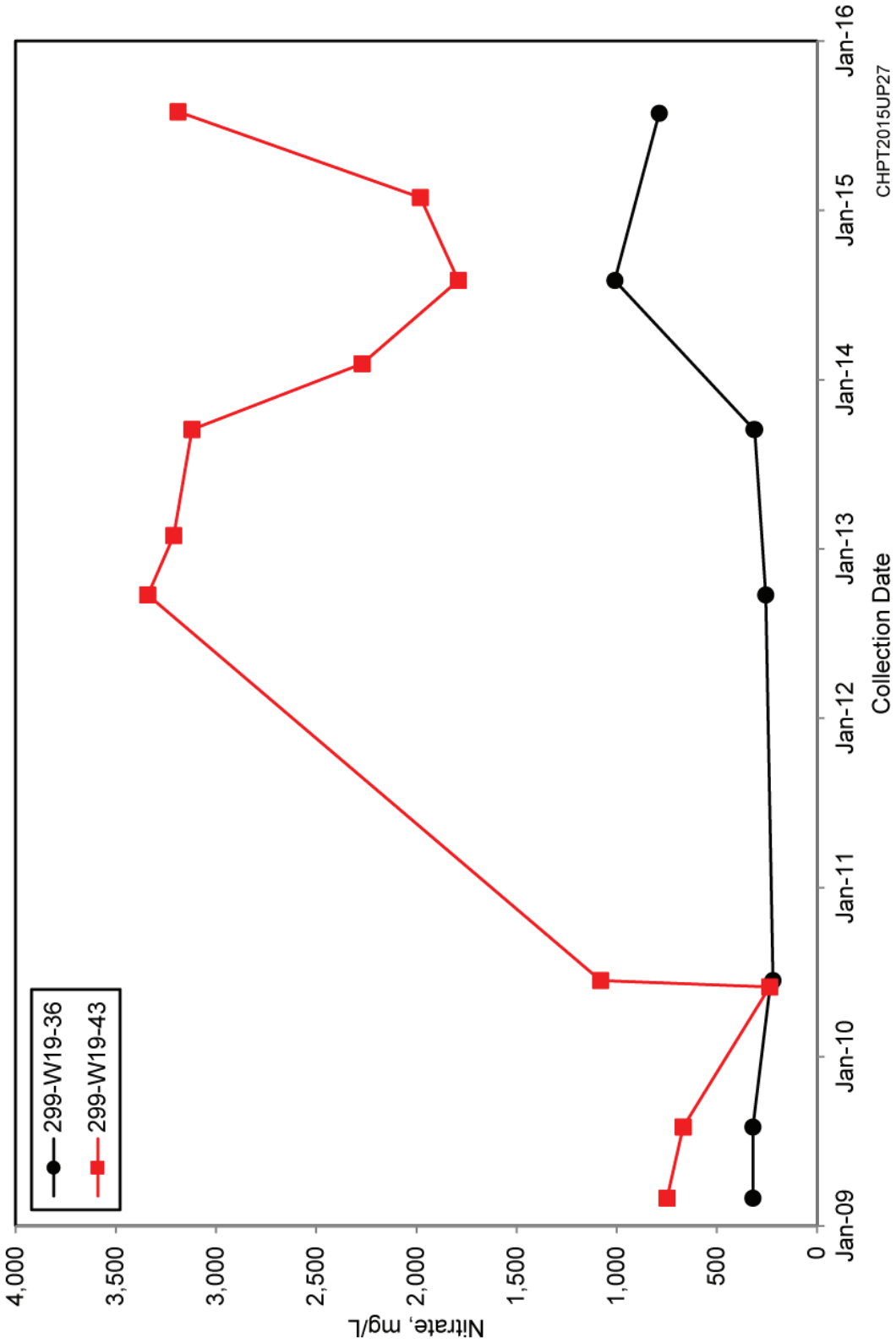


Figure 2-36. Nitrate Concentrations in Selected Wells at the U Plant Area P&T System

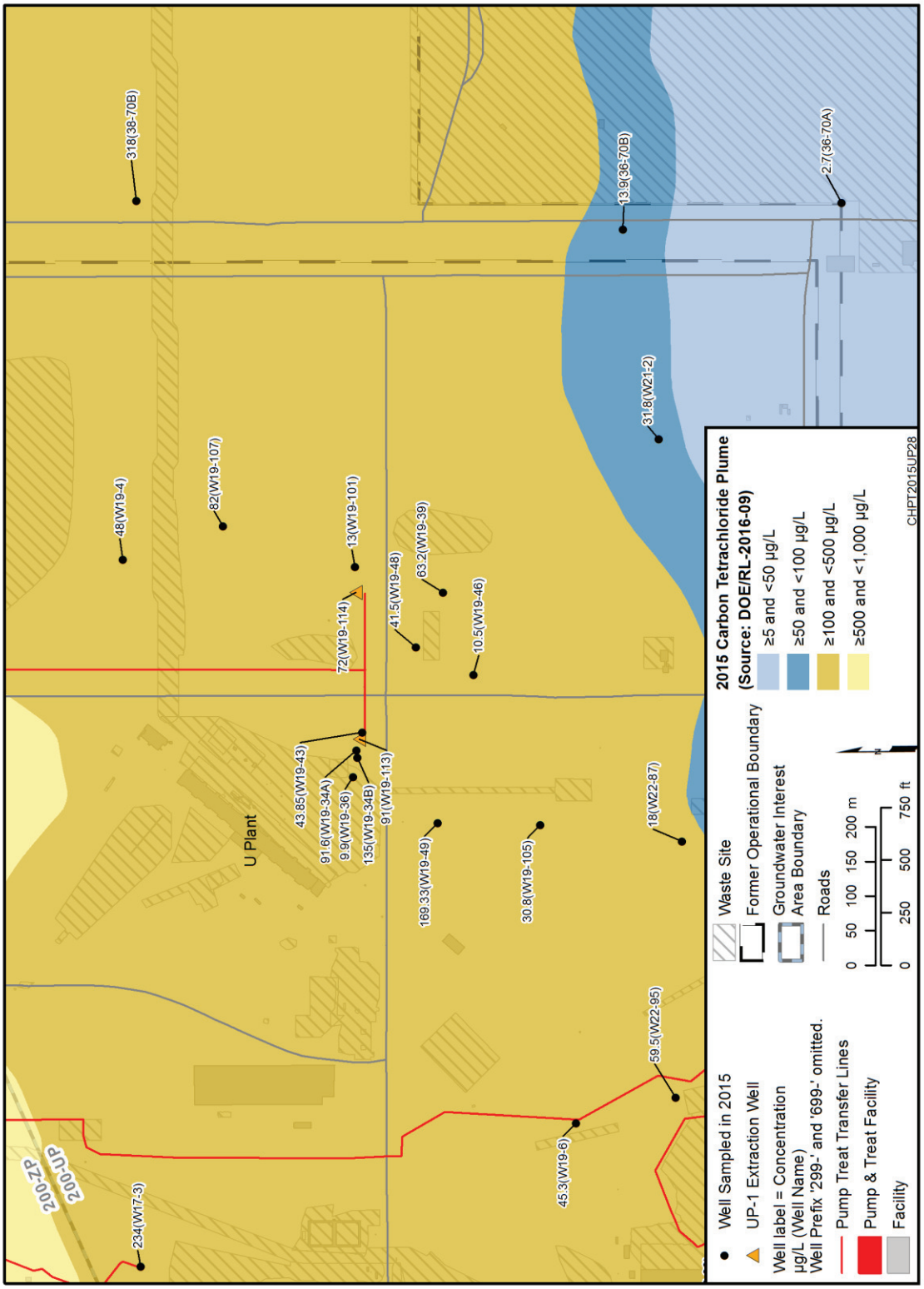


Figure 2-37. U Plant Area Carbon Tetrachloride Plume, 2015

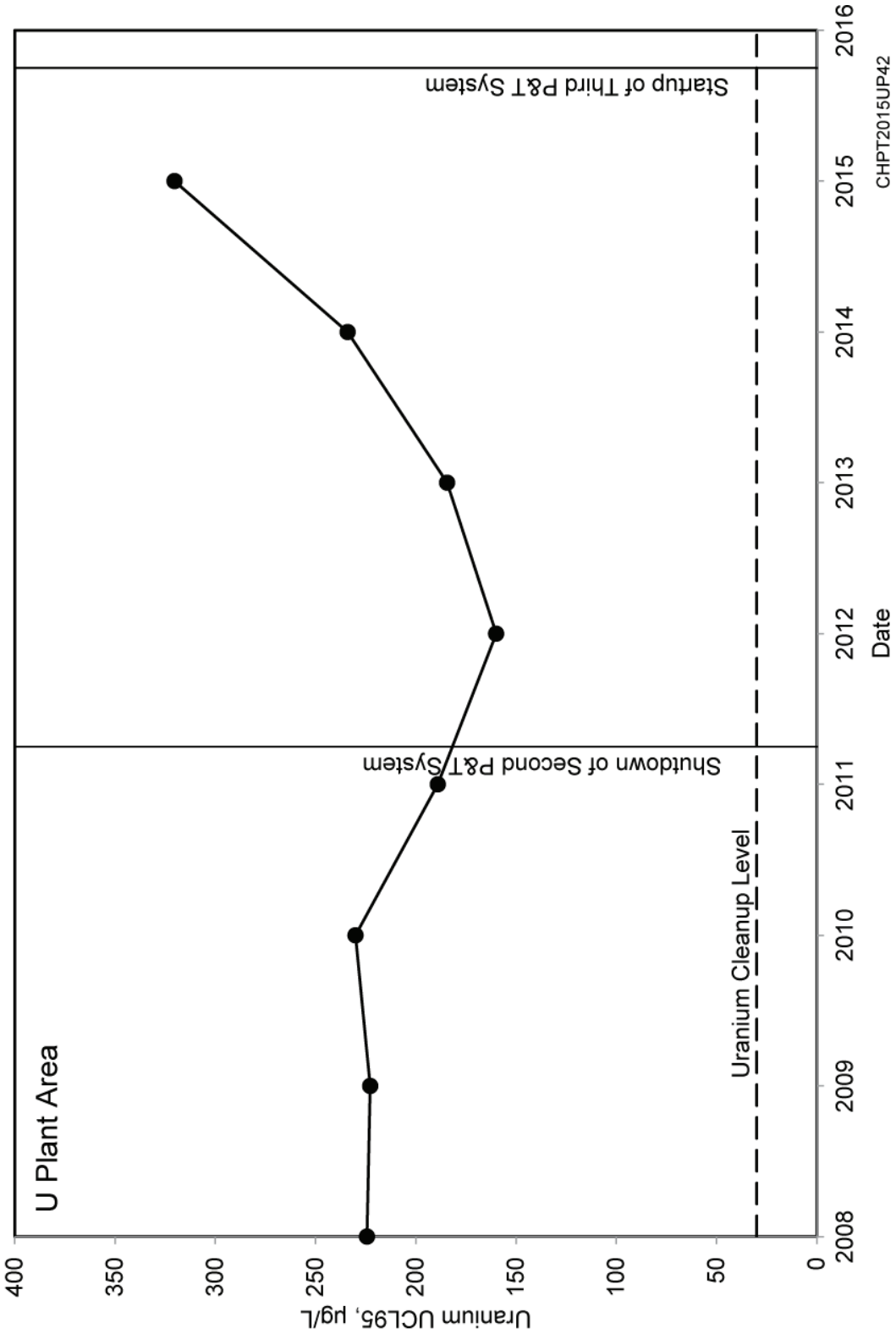


Figure 2-38. Upper Confidence Limits (95th Percentile) on the Mean Concentration of Uranium for the U Plant Area P&T System

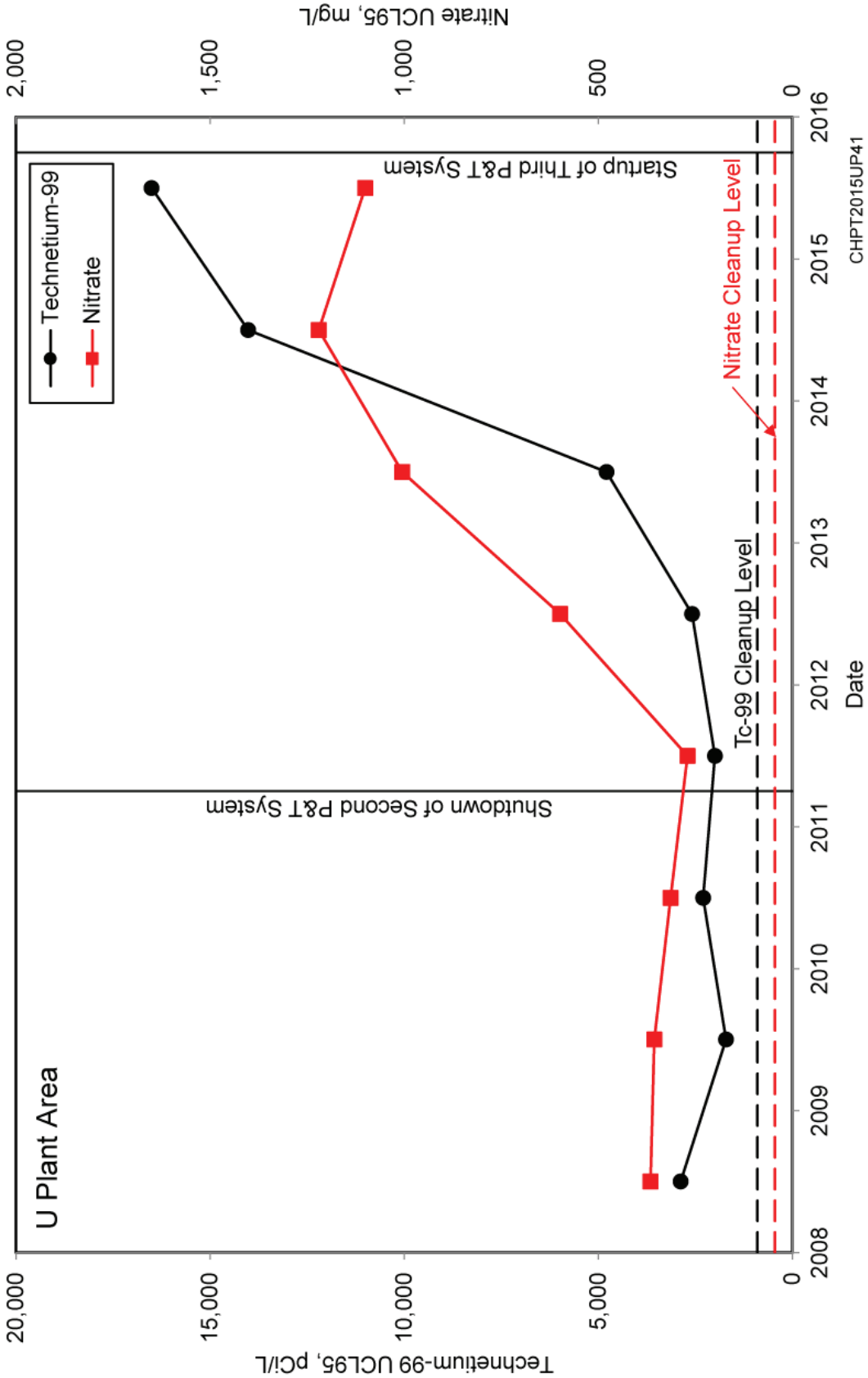


Figure 2-39. Upper Confidence Limits (95th Percentile) on the Mean Concentrations of Technetium-99 and Nitrate for the U Plant Area P&T System

2.4 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 2-40). The selected remedy for this plume is hydraulic containment while treatment technologies are evaluated (EPA et al., 2012). Hydraulic containment will be achieved by locating injection wells for the 200 West P&T to the east of the iodine-129 plume boundary. Operation of these wells is expected 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) (Table 3-5 in Chapter 3).

The hydraulic control injection wells were drilled during 2015 and began operating on October 28, 2015. This section describes the initial operation of this remedy. Because the wells only operated for the last 2 months of the year, the injected water is insufficient to form a hydraulic barrier; thus, it is too early to assess hydraulic containment of the plume, so it will be addressed in future annual reports.

2.4.1 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 2-40. Periodically, injection was temporarily ceased for system maintenance; the longest of these instances lasted 3 days from October 31 to November 2, 2015. However, the system operated greater than 90 percent of the time after startup on October 28 through December 31, 2015.

2.4.1.1 Injection Well Flow Rates

The iodine-129 plume hydraulic containment injection wells were designed to operate at a minimum nominal flow rate of 189 L/min (50 gpm) to a maximum of 379 L/min (100 gpm) per well. Between startup and the end of the year, 299-E20-1 operated at an average rate of 249 L/min (65.7 gpm), 299-E20-2 operated at an average rate of 210 L/min (55.5 gpm), and 299-E11-1 operated at an average rate of 290 L/min (76.5 gpm), which meets the design objective. The combined average flow rate for all three wells was 748 L/min (198 gpm) or 132 percent of the minimum nominal flow rate. The total volume of water injected into the aquifer during 2015 was 70.1 million L (18.5 million gal).

2.4.2 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 2-3). 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), which will be used for hydraulic control monitoring, will be drilled 425 m southwest of 299-E11-1 (shown in Figure 2-3). The baseline water table is shown in Figure 2-41 for March 2015. 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 2.1, the larger gradient magnitude is caused, at least in part, by a decrease in the 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 could decrease toward the east, which would also contribute to the larger hydraulic gradient magnitude.

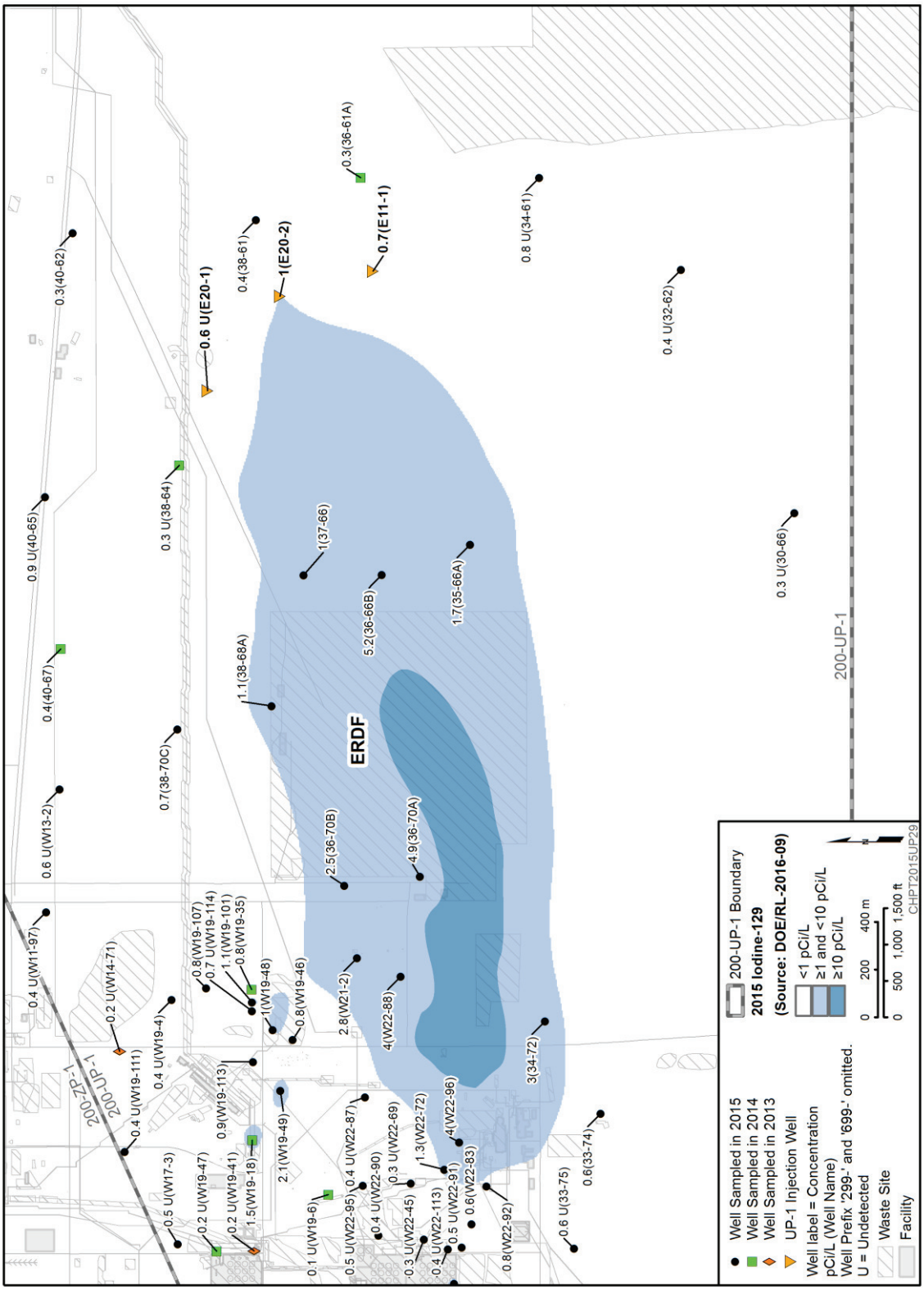


Figure 2-40. Iodine-129 Plume, 2015

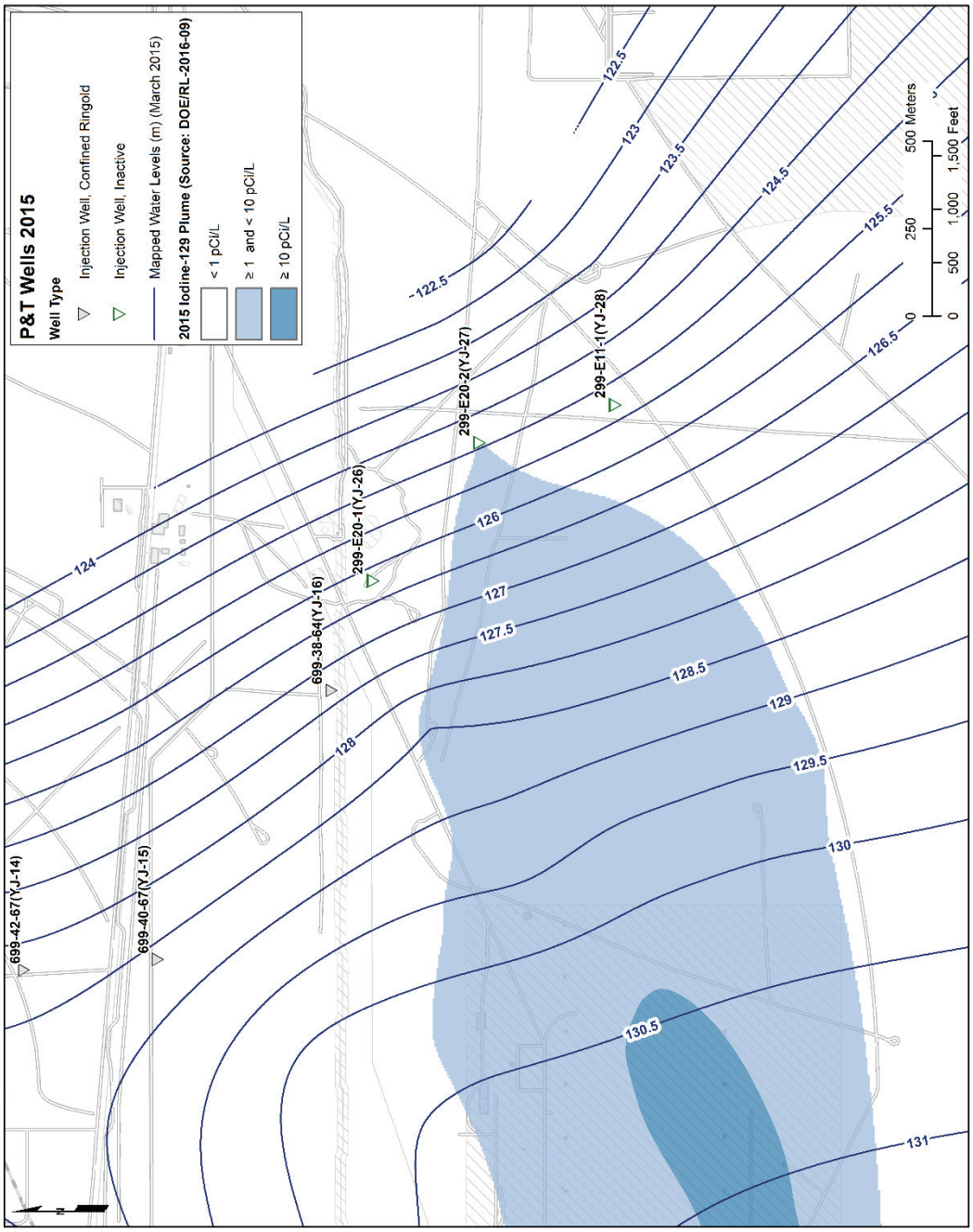


Figure 2-41. Baseline Water Table for the Iodine-129 Plume Hydraulic Containment Remedy, March 2015

The December 2015 water table map, developed by MEUK, is shown in Figure 2-42. Small groundwater mounds are evident around the injection wells. Because the wells only operated for 2 months in 2015, it is too early to assess the effect of their operation on hydraulic gradients in the area and migration of the iodine-129 plume.

2.4.3 Contaminant Monitoring

The maximum sample result in the iodine-129 plume during 2015 was 6.07 pCi/L in 699-36-66B, but wells within the highest concentration portion of the plume are dry. For example, the concentration at 699-35-70 was 37 pCi/L in March 2008 just before this well became dry. High concentrations also occurred in 299-W22-9, located along the eastern boundary of the 200 West Area. This well became dry during 2006; the iodine-129 concentration was 30 pCi/L when this well was last sampled in 2005. Both of these wells are scheduled to be replaced in 2016 or 2017.

Depth-discrete water samples were collected from the aquifer during drilling of the injection wells, and the results are shown in Table 2-13. Concentrations of iodine-129 were below the 1 pCi/L cleanup level in all the samples from 299-E20-1 and 299-E20-2, but concentrations were above the cleanup level in the two uppermost samples from 299-E11-1 (1.53±0.55 and 1.31±0.44 pCi/L). Baseline groundwater samples were collected from the constructed wells prior to the startup of injection, and the results are shown also in Table 2-13. The baseline samples from all 3 wells were below the cleanup level, although it was near the cleanup level in 299-E20-2 (0.959±0.49 pCi/L). The baseline sample results were used in constructing the iodine-129 plume map (Figure 2-40), so the plume is shown as extending to well 299-E20-2 rather than 299-E11-1 as the vertical profile sample results would suggest. The reason for this apparent discrepancy is that iodine-129 concentrations in this area are near the analytical detection limits, as shown by the relatively large magnitude in the uncertainty compared to the results (Table 2-13). Thus, there is variability in the analytical results at these low concentration levels. However, the data do indicate that wells are located near or beyond the 1 pCi/L plume contour, which was the goal when siting these wells.

2.5 Southeast Chromium Plume Characterization

Chromium occurs in groundwater southeast of the 200 West Area at concentrations above the 48 µg/L cleanup level (Figure 2-43). 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 were disposed to the 216-S-20 Crib, and an estimated 3,000 kg were 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 113 µg/L during 2015. This is similar to the concentration of 146 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.

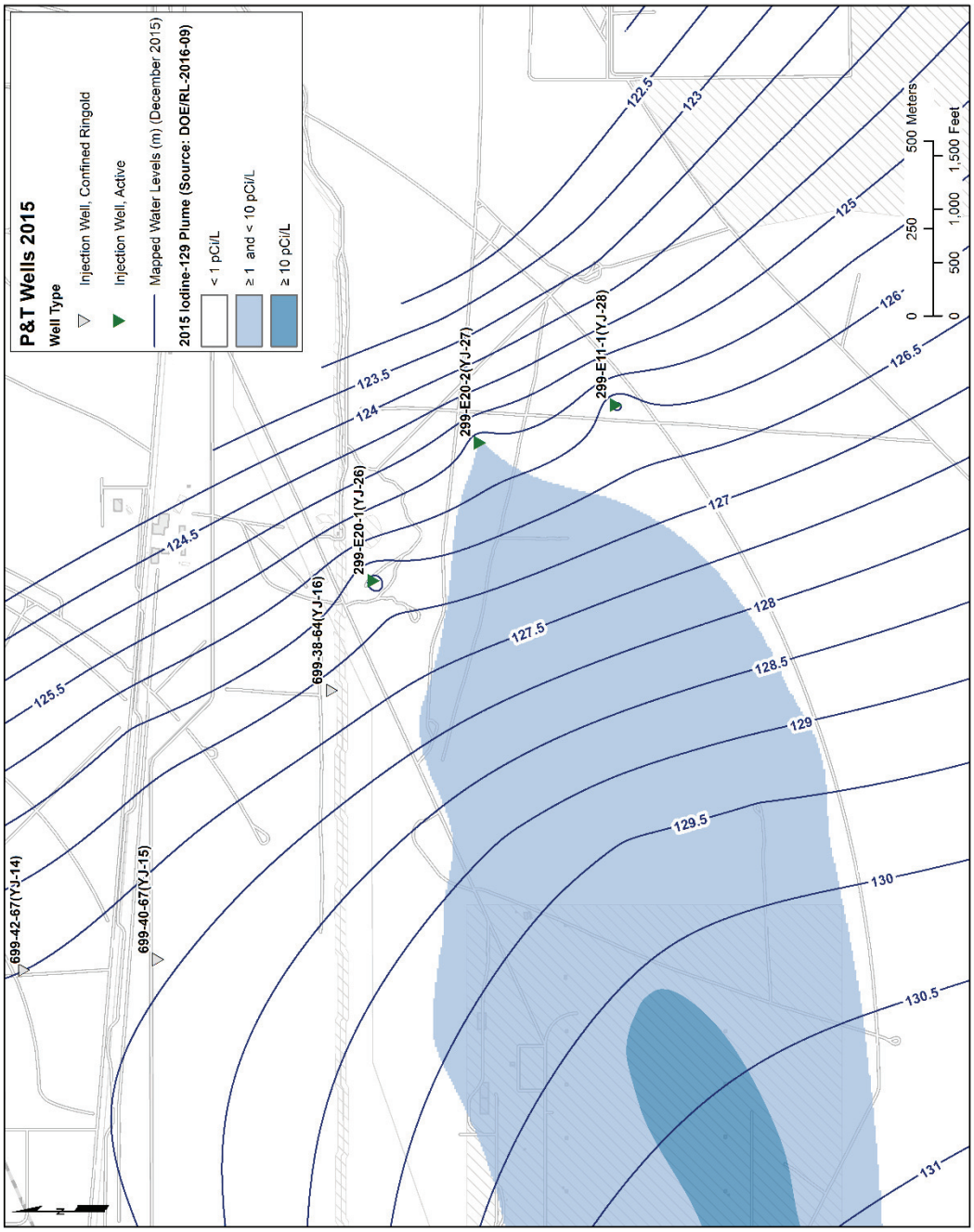


Figure 2-42. Water Table for the Iodine-129 Plume Hydraulic Containment Remedy, December 2015

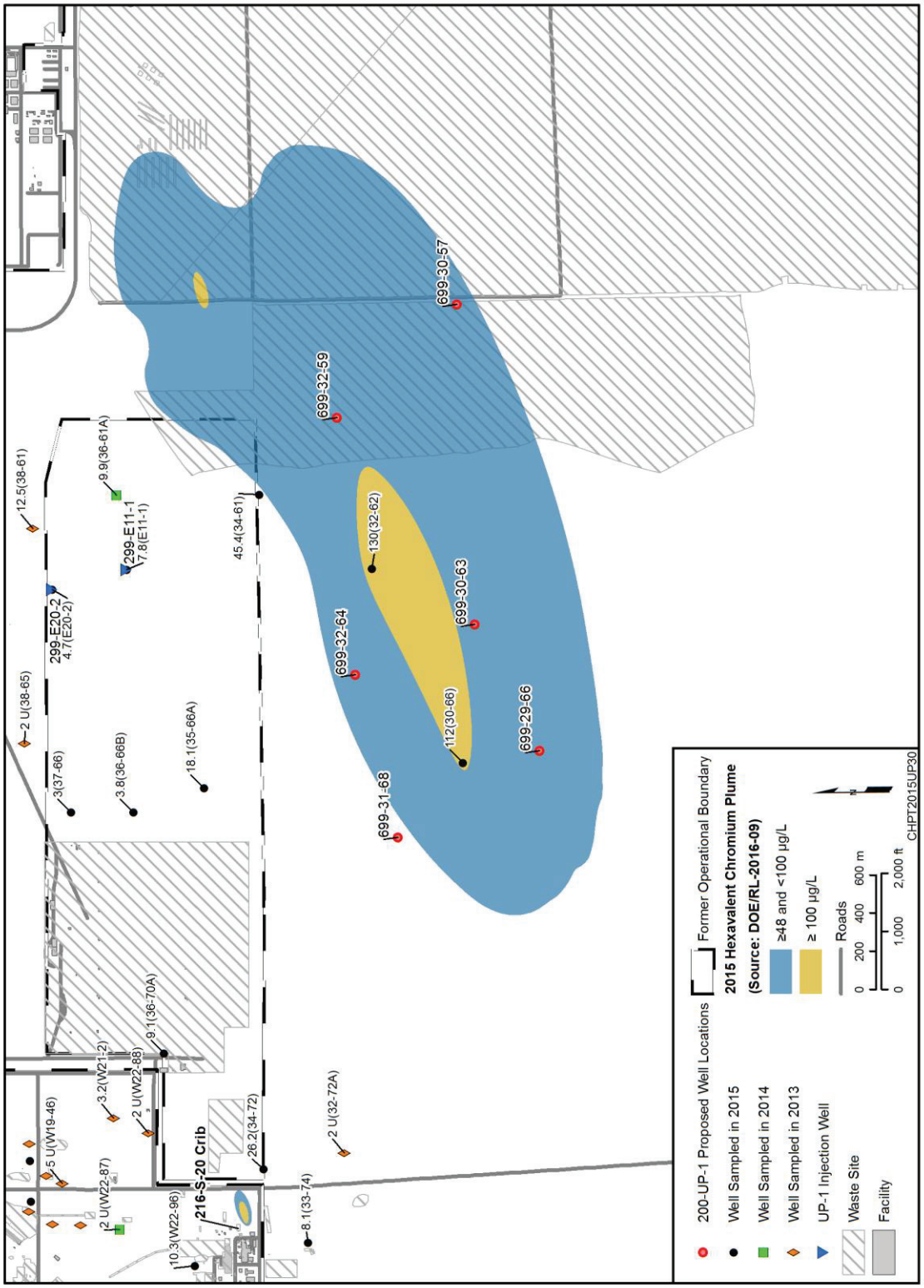


Figure 2-43. Planned Characterization Wells for the Southeast Chromium Plume

Table 2-13. Depth Profile Sample Results for the Iodine-129 Plume Hydraulic Control Injection Wells

Well Name	Depth (ft below water table)	Nitrate (mg/L as NO_3)	Iodine-129 (pCi/L)	Tritium (pCi/L)
299-E11-1	17.2	20.4	1.53 (±0.55)	124,000
	27.7	22.6	1.31 (±0.44)	159,000
	47.4	8.41	0.585 (±0.63)	115,000
	67.6	17.7	0.827 (±0.47)	88,200
	Baseline Sample	21.2	0.691 (±0.61)	113,000
299-E20-1	23.6	167	0.485U (±0.33)	20,600
	27.9	186	0.444U (±0.35)	25,600
	35.5	177	0.624U (±0.46)	23,100
	Baseline Sample	195	0.446U (±0.77)	25,300
299-E20-2	16.0	37.5	0.864 (±0.56)	133,000
	26.7	20.6	0.685U (±0.39)	78,200
	46.1	33.1	0.797 (±0.31)	99,900
	Baseline Sample	35.9	0.959 (±0.49)	102,000

U = undetected

To reduce the uncertainty in the extent of the chromium plume, additional characterization wells are planned to be drilled. Locations for six of the additional wells have been identified and are shown in Figure 2-43. The objective for three of the wells is to define the extent of contamination at the 48 µg/L concentration level (the cleanup level for hexavalent chromium) more accurately. These wells are 699-29-66 (southwest side of the plume), 699-30-57 (southeast side of the plume), and 699-31-68 (northwest side of the plume) (Figure 2-43). The purpose of the other 3 wells (699-30-63, 699-32-59, and 699-32-64) is 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). Well drilling will begin in 2016.

2.6 Monitored Natural Attenuation

MNA is specified in the interim action ROD (EPA et al., 2012) to be used in conjunction with active remedies, or as a standalone remedy in the case of tritium, to achieve RAOs. Two primary MNA mechanisms have been identified for the 200-UP-1 OU: dispersion for all COCs, and radiological decay for tritium. These mechanisms are supported by the fate and transport modeling performed for the RI/FS (DOE/RL-2009-122), which indicated that the portion of the plumes not affected by the 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/RA work plan (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 2015, but data from the previous 2 years 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 2.2.3.3, and values (uranium, technetium-99, and nitrate) for the U Plant area P&T system were presented in Section 2.3.3.4. Baseline concentrations from which MNA will be evaluated are shown in Table 2-14 for tritium and Table 2-15 for nitrate. The 2015 tritium and nitrate plume maps for the OU constitute the baseline plumes for MNA (Figures 2-44 and 2-45, respectively).

Table 2-14. Tritium Baseline Sample Results for Monitored Natural Attenuation

Well Name	Tritium (pCi/L)[a]
299-W22-113	50,300
299-W22-45	47,200
299-W22-69	4,580
299-W22-72	14,700
299-W22-83	8,890[b]
299-W22-86	9.700
299-W22-88	13,800
299-W22-96	5,110
299-W23-19	11,700
299-W23-21	37,700
299-W23-4	54,000
699-32-62	5,310
699-32-72A	41,400
699-33-74	16,200
699-34-61	8,150
699-34-72	12,600
699-35-66A	76,900
699-35-78A	<300[c]
699-36-61A	36,000
699-36-66B	271,000[b]
699-36-70A	39,600[b]
699-36-70B	9,010[b]

Table 2-14. Tritium Baseline Sample Results for Monitored Natural Attenuation

Well Name	Tritium (pCi/L)[a]
699-37-66	52,700
699-38-61	75,700
699-38-65	39,800[b]
699-38-68A	8,790[b]
699-40-62	4,940

a. Sampled during 2015 unless otherwise noted.
b. Maximum of duplicate sample results.
c. Sampled during January 2014.

Table 2-15. Nitrate Baseline Sample Results for Monitored Natural Attenuation

Well Name	Nitrate (mg/L)[a]
299-W15-37	76.1[b]
299-W18-15	58.4
299-W18-21	28.3
299-W18-40	68.6
299-W19-44	56.2
299-W19-45	111[b]
299-W19-47	67.7
699-36-66B	51.8[b]
699-36-70B	89.9[b]
699-37-66	156[b]
699-38-65	190[b]
699-38-68A	181[b]
699-38-70C	178[b]
699-40-62	128
699-40-65	216

a. Sampled during 2015.
b. Maximum of duplicate sample results.

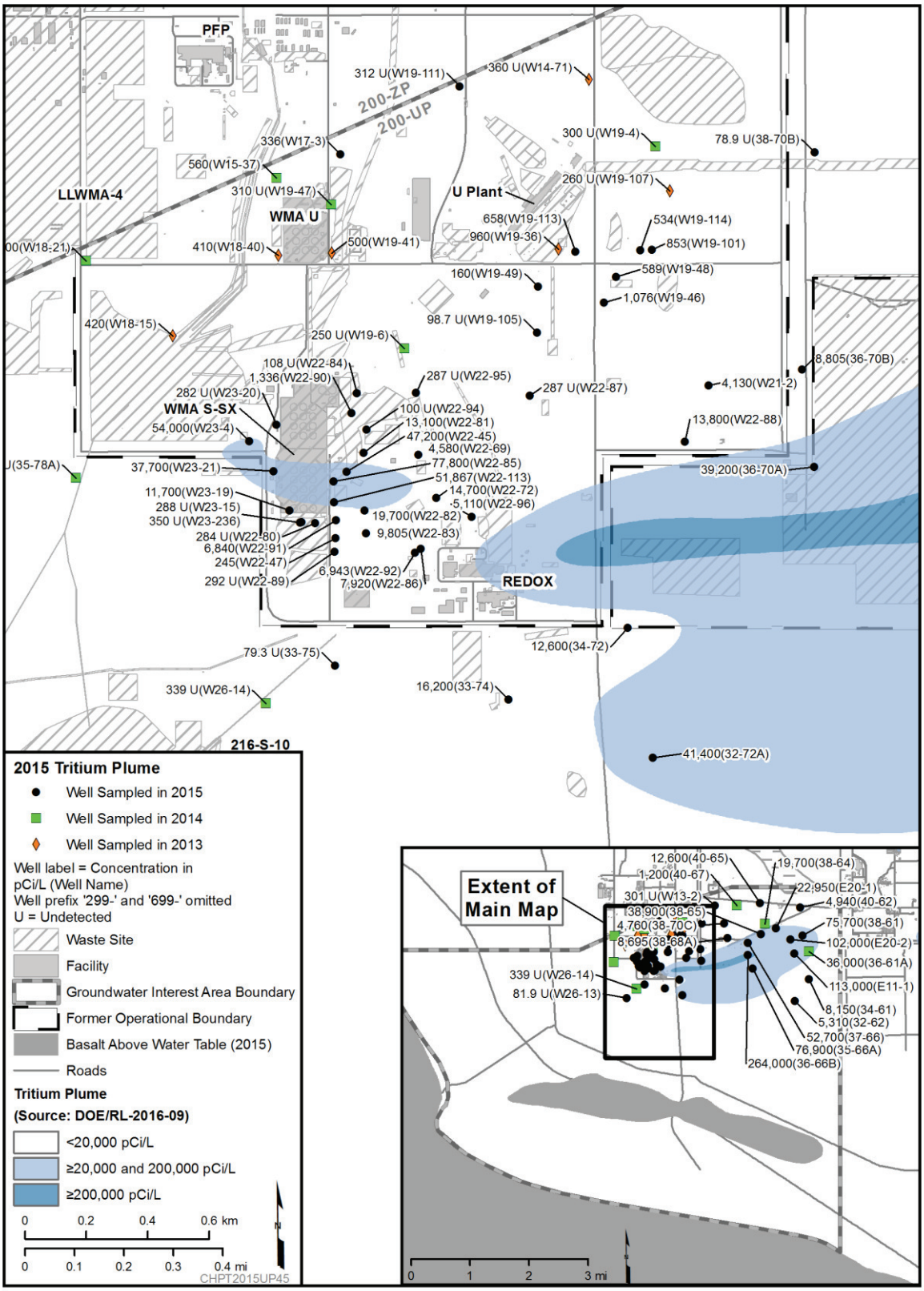


Figure 2-44. 200-UP-1 Tritium Plume Map, 2015

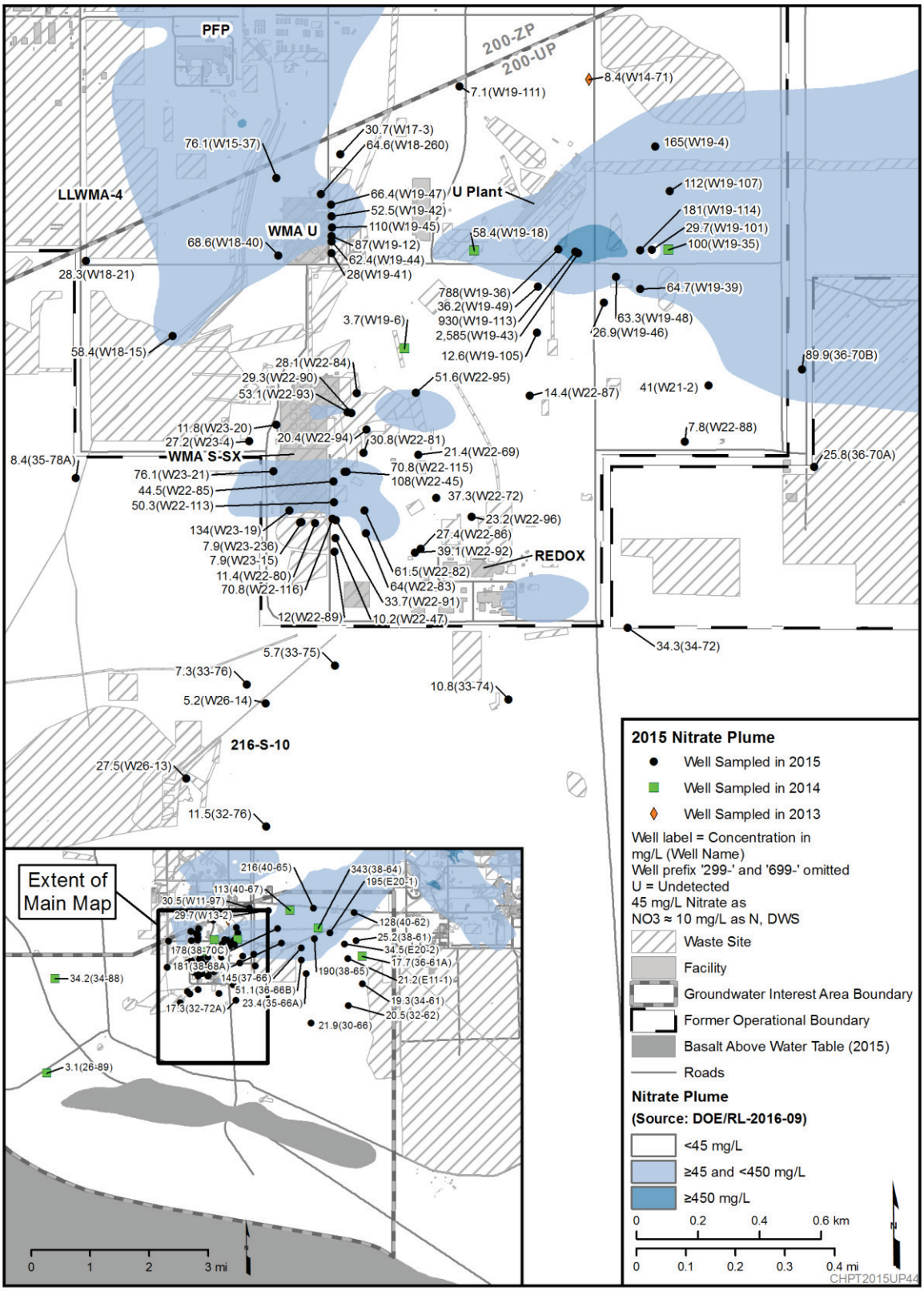


Figure 2-45. 200-UP-1 Nitrate Plume Map, 2015

UCL_{95} values for tritium and nitrate from 2008 to 2015 are shown in Figure 2-46. The tritium UCL_{95} values range between 50,100 and 86,900 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 (a replacement well is scheduled for drilling during 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 the Environmental Restoration Disposal Facility (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 nitrate UCL_{95} values range between 93 and 124 mg/L and exhibit a slight upward trend (Figure 2-46). 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.

2.7 Quality Assurance/Quality Control

Discussion on the QA/QC encompassing sampling and analysis of the 200-UP-1 OU wells is provided in Appendix F of DOE/RL-2016-09. The discussion includes an overall view of QA/QC issues that may affect interpretation of the groundwater data presented in this report.

2.8 Remedial System Costs

Tables 2-16 through 2-18 present the actual cost breakdown for the WMA S-SX groundwater extraction system, U Plant area P&T system design and construction, and iodine-129 plume hydraulic containment design and construction for 2015. 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.

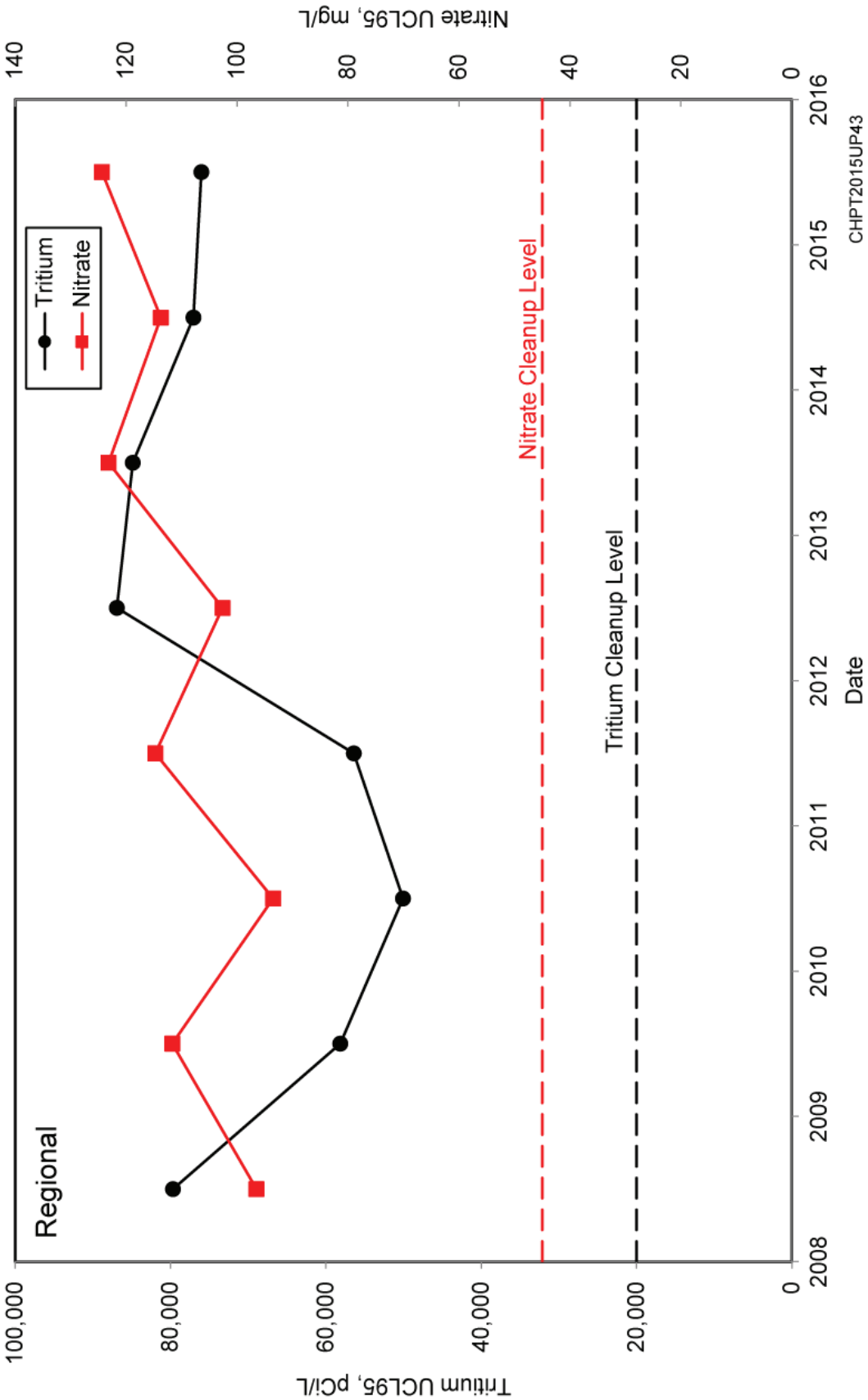


Figure 2-46. Upper Confidence Limits (95th Percentile) on the Mean Concentrations of Tritium and Nitrate for the 200-UP-1 OU

Table 2-16. Cost Breakdown for the WMA S-SX Groundwater Extraction System

Description	Actual Costs (in Thousands)					
	2010	2011	2012	2013	2014	2015
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
Operations and Maintenance	--	--	--	$36.1	$41.0	$12.3
Performance Monitoring	--	$17.3	$12.7	$53.7	$62.7	$40.8
Well Installation	--	$1,177.4	--	--	--	--
Totals	**$1,636.5**	**$5,302.6**	**$192.3**	**$98.9**	**$107.0**	**$60.8**

Table 2-17. Cost Breakdown for the U Plant Area P&T System

Description	Actual Costs (in Thousands)	
	2014	2015
Design	$1,449.5	$69.3
Construction	$2,461.4	$6,951.7
Project Support	$291.3	$81.1
Operations and Maintenance	$0.0	$40.1
Performance Monitoring	$0.0	$12.8
Well Installation	$781.9	$766.4
Totals	**$4,984.1**	**$7,921.4**

Table 2-18. Cost Breakdown for the Iodine-129 Hydraulic Containment System

Description	Actual Costs (in Thousands)	
	2014	2015
Design	$121.3	$130.9
Construction	$36.6	$2,004.6
Project Support	$63.0	$51.6
Operations and Maintenance	$0.0	$0.0
Performance Monitoring	$0.0	$0.0
Well Installation	$1.6	$2,048.6
Totals	**$222.5**	**$4,235.7**

- **Operations and maintenance (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 are addressed under the 200-ZP-1 OU as part of the overall 200 West P&T system costs (Table 3-9 in Chapter 3).
- **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.
- **Waste management:** Consists of the estimated cost for the management of generated wastes in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Waste designation sampling and analysis are included. Waste management costs for the WMA S-SX groundwater extraction system and U Plant area P&T are addressed under the 200-ZP-1 OU as part of the overall 200 West P&T system costs (Table 3-9 in Chapter 3).
- **Well installation:** This includes costs for the installation of new *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring, extraction, and injection wells at the 200-UP-1 OU.

2.9 Conclusions

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

- The WMA S-SX groundwater extraction system is able to operate at its design capacity. During 2015, the combined pumping rate from the three extraction wells averaged 348 L/min (92 gpm), or 115 percent of the design nominal pumping rate of 303 L/min (80 gpm).
- During 2015, the WMA S-SX groundwater extraction system extracted 183 million L (48.3 million gal) of water, containing an estimated 30.6 g (0.520 Ci) of technetium-99, 8.0 kg of chromium, 6,320 kg of nitrate, and 12.4 kg of carbon tetrachloride from the aquifer. The total mass removed since startup was 128.6 g (2.18 Ci) of technetium-99; 36.1 kg of chromium; 22,600 kg of nitrate; and 39.5 kg of carbon tetrachloride.
- Capture zones from the extraction wells for the WMA S-SX groundwater extraction system effectively cover most of the high-concentration portion of the technetium-99 plume.
- 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 9,640 pCi/L between 2011 and 2015 due to operation of the groundwater extraction system.
- During 2015, construction of the U Plant area P&T system (the third 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. Modifications to the 200 West P&T radiological building to add an IX treatment train to remove uranium from the extracted water were also completed during 2015. Additional wells will be installed beginning in 2016 to monitor the

uranium plume, and three of the wells will be designed as dual use monitoring/extraction wells in the event that system optimization analyses indicate that additional extraction capacity is needed.

- The U Plant area P&T system began operating during September 2015. Between startup and the end of the year, the extraction wells operated at a combined average rate of 468 L/min (124 gpm), which was 82 percent of the nominal design rate of 568 L/min (150 gpm); however, the system achieved its design rate in early 2016.
- During 2015, the U Plant area P&T system extracted 65.4 million L (17.3 million gal) of water, containing an estimated 1.8 kg of uranium; 11.0 g (0.19 Ci) of technetium-99; 22,300 kg of nitrate; and 5.3 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 percent of the areal extent of the uranium plume above 30 µg/L and about 70 percent of the plume above 300 µg/L. Concentrations in the portions of the plume that are not being captured are predicted to decline to below the cleanup level by natural attenuation (DOE/RL-2009-122). The capture zones cover nearly all of the technetium-99 plume and the entire high-concentration portion of the nitrate plume (i.e., greater than 450 mg/L), as designed. 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.
- Groundwater sample results for the U Plant area P&T system were used to establish baseline concentrations from which future remediation progress will be evaluated. UCL_{95} values calculated annually from 2008 to 2015 ranged between 160 and 320 µg/L for uranium; 1,710 and 16,500 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.
- Injection wells for the iodine-129 plume hydraulic containment system were drilled during 2015 and began operating in late October. Operation of these wells will 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. Between startup and the end of the year, 299-E20-1 operated at an average rate of 249 L/min (65.7 gpm), 299-E20-2 operated at an average rate of 210 L/min (55.5 gpm), and 299-E11-1 operated at an average rate of 290 L/min (76.5 gpm), which meets the design objective.
- To design the P&T system for the southeast chromium plume, additional information is needed regarding plume extent. To obtain this information, additional characterization wells are planned to be drilled starting in 2016.
- MNA was evaluated statistically by calculating the one-sided UCL_{95} on the mean of the tritium and nitrate plume concentrations for the OU. Between 2008 and 2015, annual tritium UCL_{95} values ranged between 50,100 and 86,900 pCi/L, and nitrate values ranged between 93 and 124 mg/L. Recent UCL_{95} values for tritium have been declining probably due to dispersion and radiological decay of the plume. The nitrate UCL_{95} trend is increasing, due to increasing nitrate concentrations in the vicinity of the U Tank Farm, and originating at least partly upgradient.

2.10 Recommendations

The following recommendations are made for the 200-UP-1 OU:

- Substantial progress has been made in remediating the technetium-99 plume at WMA S-SX as evidenced by the reduction in the annual UCL_{95} concentration value from an average of 20,200 pCi/L prior to system startup to 9,640 pCi/L during 2015. Thus, the WMA S-SX groundwater extraction system is functioning, as intended, and should continue to be operated at current flow rates.
- The capture zone achieved by the U Plant area extraction wells is very similar to the design capture zone, indicating that the system should function as intended. However, it is recommended that after at least 1 year of operations and performance monitoring data become available, system performance should be re-evaluated by numerical modeling to ensure that remediation objectives will be achieved. If this modeling indicates that remediation objectives will not be achieved with the current system, then alternatives to improve capture will be investigated.
- The iodine-129 hydraulic control remedy began operating near the end of the year. It is recommended that the system continue to operate at current flow rates until at least 1 year of performance monitoring data are available to evaluate hydraulic containment.
- Remedy performance monitoring wells are being drilled to replace wells that have gone dry and to establish new monitoring locations as part of Tri-Party Agreement (Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*) Milestone M-193. It is recommended that the details of this effort be described in a revision to the PMP (DOE/RL-2015-14).

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3 200-ZP-1 Operable Unit Remedial Actions

This chapter discusses the remedial activities performed within the 200-ZP-1 OU during 2015, including activities associated with the 200 West P&T. In 2015, an IX system was installed in the 200 West P&T radiological building to treat uranium contaminated water from both the 200 West and 200 East Areas. The 200 West P&T is designed to remove carbon tetrachloride, total chromium and hexavalent chromium, nitrate, technetium-99, trichloroethene (TCE), low concentrations of iodine-129, and now uranium from contaminated water using IX, anoxic and aerobic bioreactors, and air stripping. Operation of the 200 West P&T system is important for mitigating the migration of 200-ZP-1 and 200-UP-1 contaminants to the Columbia River.

Operation of the 200 West P&T (Figure 3-1) began in 2012 initially treating contaminated water from the 200-ZP-1 OU and from WMA S-SX in the 200-UP-1 OU. The system is designed to capture and treat contaminated water and reduce the mass of COCs (listed in Table 3-1) throughout the 200-ZP-1 OU by a minimum of 95 percent in 25 years. The 200 West P&T has been implemented in combination with MNA to achieve cleanup levels listed in Table 3-1 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 regulatory framework for remediation of the OU.

In September 2015, with installation of an IX system specifically designed to remove uranium, treatment of uranium and technetium-99 contaminated water began from both the 200-UP-1 and 200-BP-5 OUs. A detailed description of the 200 UP-1 OU remedial action is found in Chapter 2. A detailed description of the 200-BP-5 treatability testing is found in DOE/RL-2015-75, *Aquifer Treatability Test Report for the 200-BP-5 Groundwater Operable Unit*.

In addition to the installation of the uranium IX system, activities performed during 2015 included installation of four new injection wells in 200-ZP-1 (to support the 200-ZP-1 OU flow-path control component); installation of three new injection wells in 200-UP-1 (for iodine-129 containment), installation of two extraction wells in 200-ZP-1 (to complete the 200-ZP-1 OU extraction well network); and installation of two extraction wells in 200-UP-1 (to remove uranium and technetium-99 contamination) to supplement the 40 well system. Additional activities included the connection and operation of one extraction well in the 200-BP-5 OU for treatability testing beginning in September 2015 and connection of three perched water wells in the 200-DV-1 OU for treatability testing to start in early 2016.

3.1 Remedial System Operation

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) will be made based on an evaluation of the data against the decision statements (DSs) (Section 3.10) initially presented in the 200-ZP-1 PMP (DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*). Table 3-2 lists the 200 West P&T performance parameters for 2015.

Figure 3-1. Aerial Photograph of the 200 West P&T

Table 3-1. Final Cleanup Levels for the 200-ZP-1 Groundwater OU

Contaminant of Concern	90th Percentile Concentration	Federal MCL	State MCL	Model Toxics Control Act Method B Cleanup Levels		Final Cleanup Level
				Non-carcinogens	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[c]	203	—[d]	—[d]	48	—	48
Iodine-129	1.2	1	1	—	—	1
Nitrate[e] (as NO_3)	359,052	45,000	45,000	113,408	—	45,000
Nitrate[e] (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 Operable Unit 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. The mobile form of chromium in Hanford Site groundwater is hexavalent chromium. Groundwater samples have been analyzed for chromium by the analytical laboratories as either total chromium or hexavalent chromium. Both methods yield similar results, although there can be differences caused by normal analytical variability or sample turbidity. Therefore, although total chromium and hexavalent chromium are listed as separate COCs, they represent the same constituent in Hanford Site groundwater. The effective cleanup level for chromium is the hexavalent chromium standard of 48 µg/L because it is more restrictive.

d. There is no MCL specific to hexavalent chromium.

e. 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 the EPA's drinking water regulations are published as 10,000 µg/L.)

— = not applicable

MCL = maximum contaminant level

Table 3-2. 200 West P&T Performance for 2015

Performance	2015	Since 2012[a]
Total Groundwater Processed (L)	3,831,506,172	10,344,691,910
Mass Removed		
Carbon Tetrachloride (kg)	2,786	9,264
Chromium (Total and Hexavalent) (kg)	83.5	249.9
Iodine-129[b] (pCi)	0.0	242,010,000
Nitrate (as NO_3) (kg)	348,431	844,113
Technetium-99 (g)	109	284
Trichloroethene (kg)	11.0	36.7
Uranium[c] (kg)	6.4	8.2
Average Mass Removal Efficiency[d]		
Carbon Tetrachloride	99.9%	99.8%
Chromium (Total and Hexavalent)	85.5%	82.8%
Iodine-129[b]	0.0%	23.5%
Nitrate (as NO_3)	78.2%	70.4%
Technetium-99	94.9%	96.3%
Trichloroethene	91.5%	85.6%
Uranium[c]	97.4%	97.4%
System Availability[e]	>90%	>90%
Plume Area at 2,000 µg/L (km^2)	0	0.29

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

b. In 2015, 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)].

3.1.1 Overview of Remedial System

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 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 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 then pumped through particulate filters (to remove suspended materials), and then 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 200-UP-1 and 200-ZP-1 OUs (1-3 µg/L background concentrations). The blended water is then pumped through particulate filters (to remove suspended materials) and then passes through two parallel IX treatment trains containing Purolite® A530E resin. This resin, which has proven effective in removing technetium-99, 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 (anticipated to occur in CY 2016), the resin will be transferred to a separate tank where it will be heated to 71°C (160°F) to remove VOCs prior to disposal at ERDF.

For 2015, the biological treatment building has a maximum flow capacity of 9,464 L/min (2,500 gpm), which includes recirculated water, resulting in a nominal flow of 9,092 L/min (2,000 gpm). 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 fluidized bed reactors (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 percent 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 then disposed at ERDF. The final treated water is then pumped to the injection well field. Figure 3-2 depicts the entire project, including the pipelines. Figure 3-3 illustrates the various components and pathways of the 200 West P&T.

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® Purolite is a registered trademark of Brotech Corporation, Bala Cynwyd, Pennsylvania.

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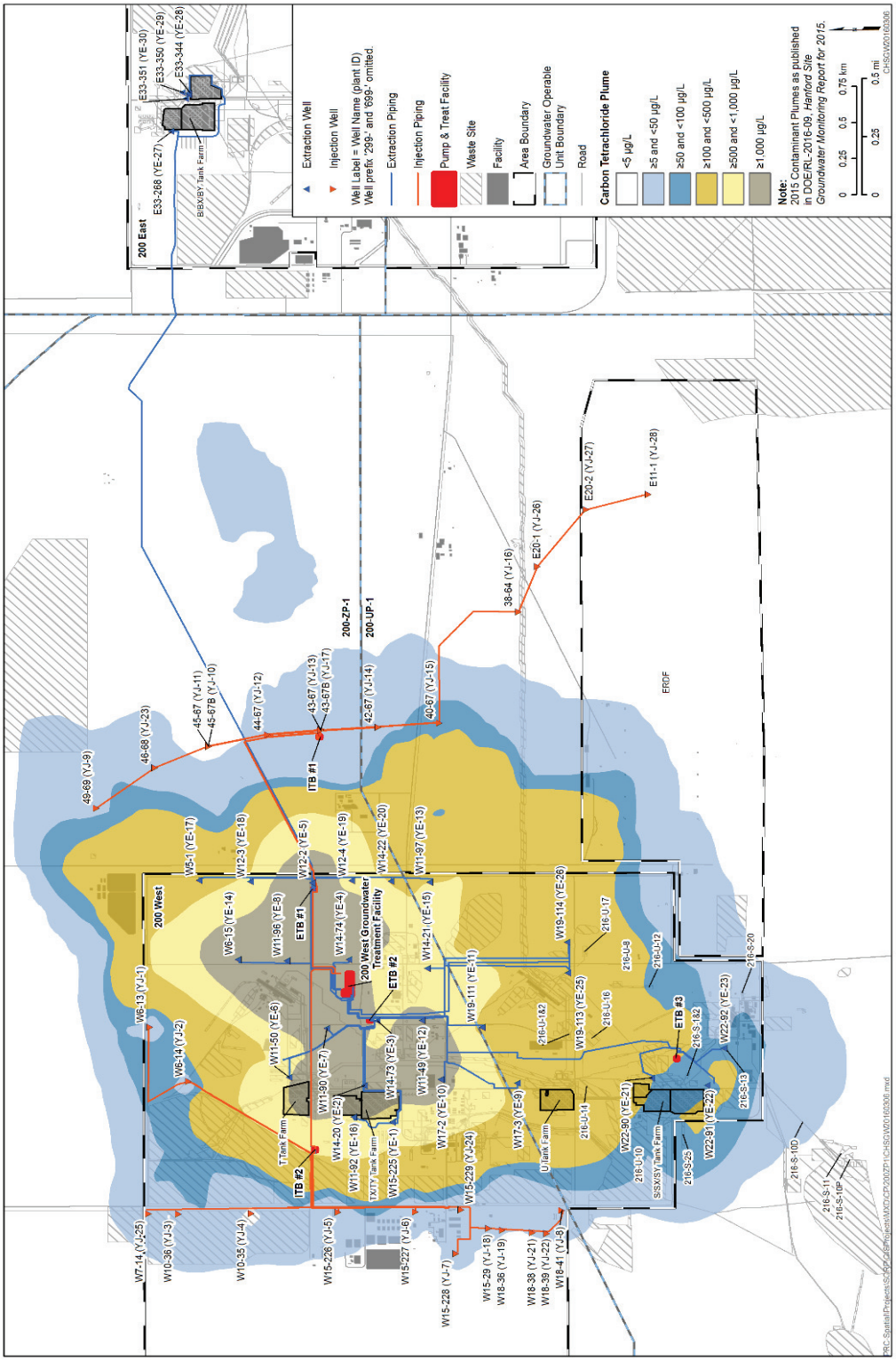


Figure 3-2. 200 West P&T with Project Components, Well Locations, and Piping Routes

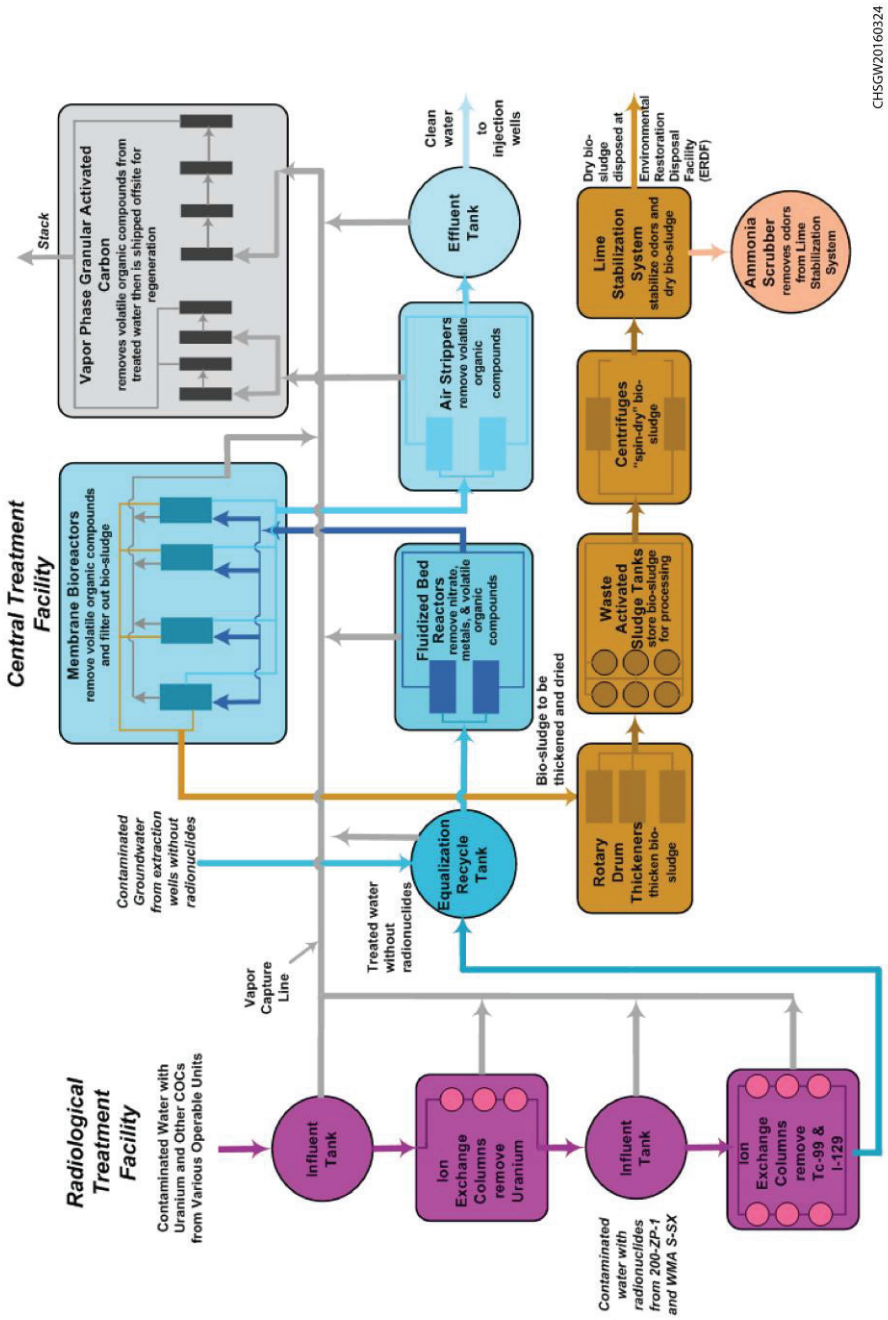


Figure 3-3. 200 West P&T Treatment Process

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, 200-UP-1, and 200-BP-5 OUs. The new 200-ZP-1 and 200-UP-1 extraction wells are 20 cm (7.9 in.) in diameter with long screens (greater than 30 m [98 ft]) placed to within 3 m (9.8 ft) of the bottom of each well. The new 200-BP-5 extraction well is 20 cm (7.9 in.) in diameter and screened across the 2.2 m (7.5 ft) unconfined aquifer. Extraction well screens in 200-ZP-1 OU target intervals with carbon tetrachloride concentrations greater than 100 µg/L. Extraction well screens in 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. The spacing of the extraction wells in 200-ZP-1 OU was determined through aquifer testing and groundwater modeling to be sufficient to capture contaminants at elevated concentrations throughout the aquifer underlying the 200-ZP-1 OU (DOE/RL-2010-13, *200 West Area Groundwater Pump-and-Treat Remedial Design Report*). The new 200-BP-5 extraction well was located based on the capture zone numerical simulations, the unconfined aquifer's saturated thickness, proximity of existing wells for use as monitoring wells, and proximity of the defined uranium and technetium-99 plumes (DOE/RL-2010-74, *Treatability Test Plan for the 200 BP-5 Groundwater Operable Unit*).

Some of the treated water is injected to the northeast and east of the 200-ZP-1 OU extraction wells to reduce and locally reverse the natural eastward hydraulic gradient in the aquifer and to minimize the potential for groundwater in the northern portion of 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). Mounding of groundwater in the aquifer from these wells slows the natural eastward flow and keeps the majority of the COCs within the hydraulic capture zone of the extraction wells, enabling natural attenuation to reduce contaminant concentrations. 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.

3.1.2 Remedial System Monitoring Data

The initial baseline data for 200-ZP-1 OU, collected in 2012 prior to the startup of the 200 West P&T, will be used for comparison with 2015 data from 200-ZP-1 and in future years to provide a basis 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 in order to assess the success of the remedy 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, as well as uranium (200-UP-1 OU source), which is present within some wells in the monitoring well network.

3.1.2.1 Extraction and Injection Well Flow Rates

This subsection describes the volume of water removed by the extraction wells and the changes to the well network during the year.

The 200 West P&T extraction system pumped 3.8 billion L (1.1 billion gal) of water in 2015. Flow rates for each of the 200 West P&T extraction and injection wells in 2015 are summarized in Figures 3-4 through 3-7. Extraction wells in the 200-ZP-1 OU are designed to produce between 303 and 492 L/min (80 and 130 gpm). Injection wells are designed to have an injection capacity of 568 L/min (150 gpm). During 2015, extraction wells produced according to design with two exceptions (299-W12-3 and 299-W14-21). These two wells were offline much of 2015 for maintenance. Both wells had well pump issues and were not repaired before freezing weather arrived. Injection wells, however, declined in injection capacity as a result of continued biofouling from the FBRs and minerals (e.g., iron and manganese) in the effluent that clogged well screens. Biofouling of the injection wells, initially detected in 2013, 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. CHPRC scientists determined the proper micronutrient and carbon substrate feed to the FBRs, providing for healthier microorganisms, and the production of slimy biomass greatly declined. However, thorough removal of biofouling and mineral deposits within the wells is difficult, requiring multiple cleanings of each injection well to restore injection capacity. Flows through the system in 2015 were reduced as injection wells were taken offline and cleaned to remove the clogging material.

3.1.2.2 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 2015 (January through December) are presented in Table 3-3. Section 3.3 discusses the COC data from the extraction and monitoring wells.

3.1.2.3 Treatment Plant Influent and Effluent Flow Rates

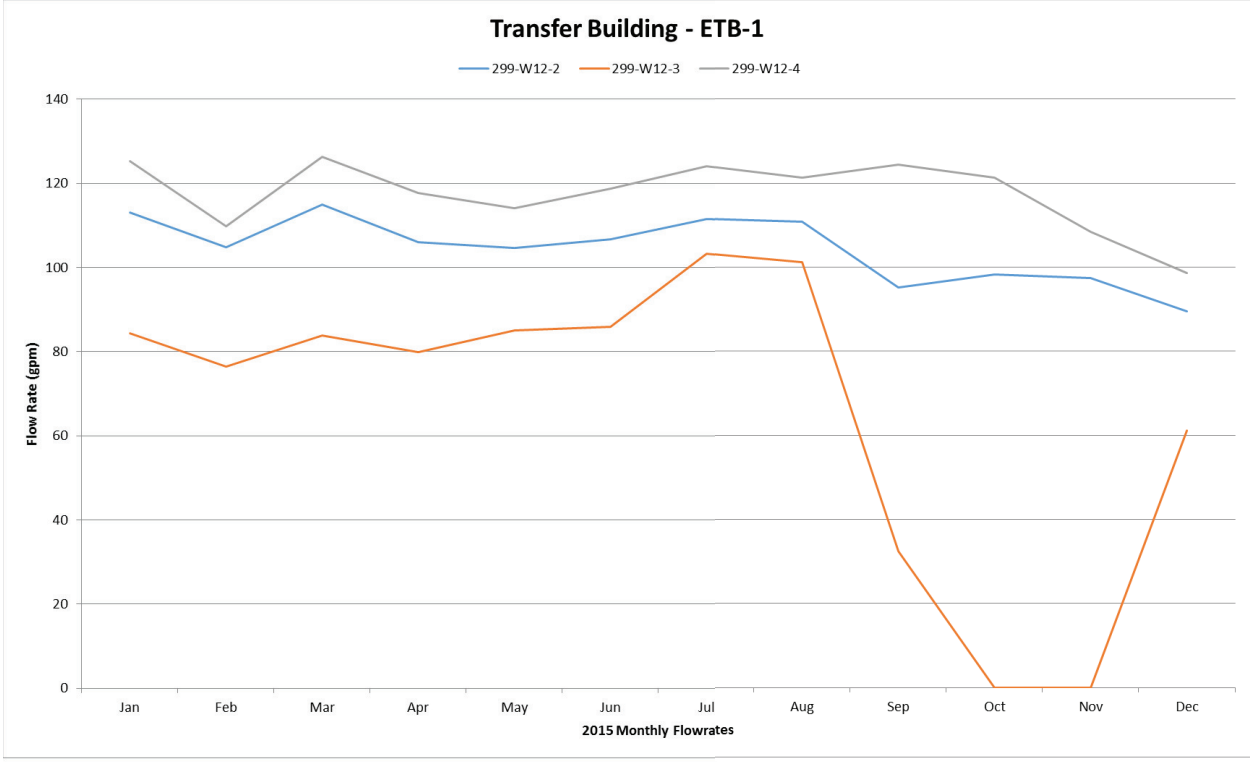
Flow rates for extraction and injection wells are adjusted to maximize contaminant mass removal and are not constant. Table 3-4 shows the water processed and average calculated flow rate. Flow through the system varied between 5,930 and 7,410 L/min (1,570 and 1,960 gpm) in 2015.

3.1.2.4 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 2015 are presented in Table 3-5. The concentration of all COCs in the effluent were below the cleanup levels listed in Table 3-1, except for nitrate in the analytical sample collected in December. The concentration for nitrate in the December 8, 2015 sample was 62 mg/L, which is over the 45 mg/L cleanup value. However, process samples collected during the month averaged less than 45 mg/L.

3.1.2.5 Analysis of Remedial System Monitoring Data

For 2015, the 200 West P&T operated at an average flow rate from 26 extraction wells of 7,447 L/min (1,966 gpm) (98 percent of the nominal 7,575 L/min [2,000 gpm] flow design). Concentrations of COCs in the treated water sent to the 26 operational injection wells in 2015 were at or below cleanup levels. During 2015, the 200-ZP-1 monitoring well network (consisting of 50 monitoring wells) was sampled for all COCs. Sample data in 2015 from most monitoring wells and extraction wells indicated that COC concentrations are declining. 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 was almost entirely contained by pumping in the 200 West Area as of 2015.



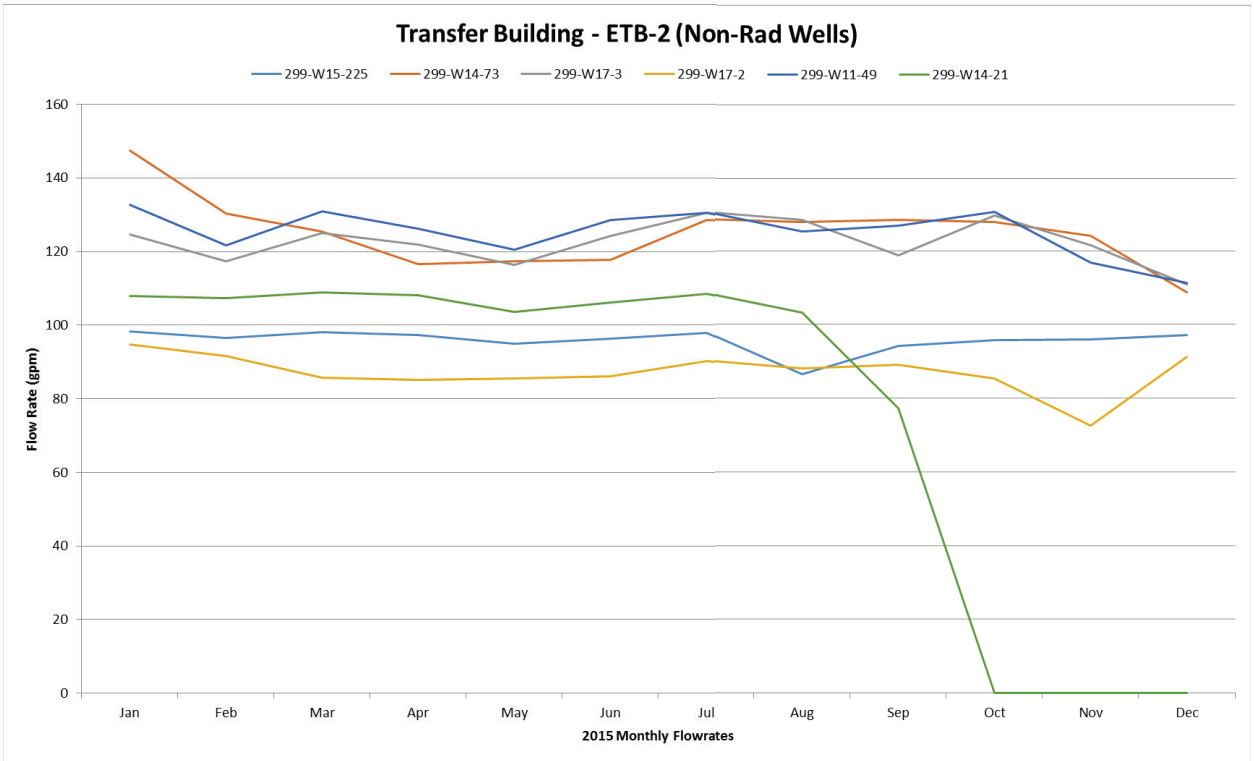
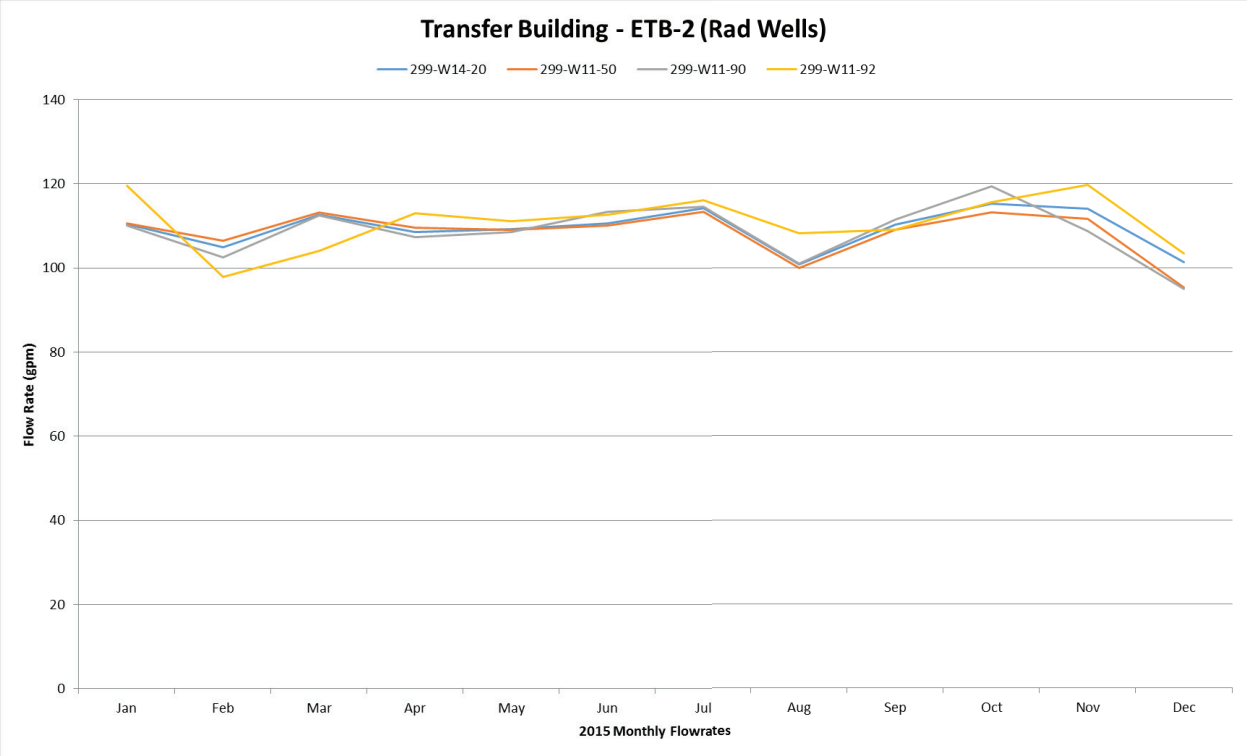


Figure 3-4. 200 West P&T Flow Rates for Extraction Wells without Radiological Contaminants, 2015



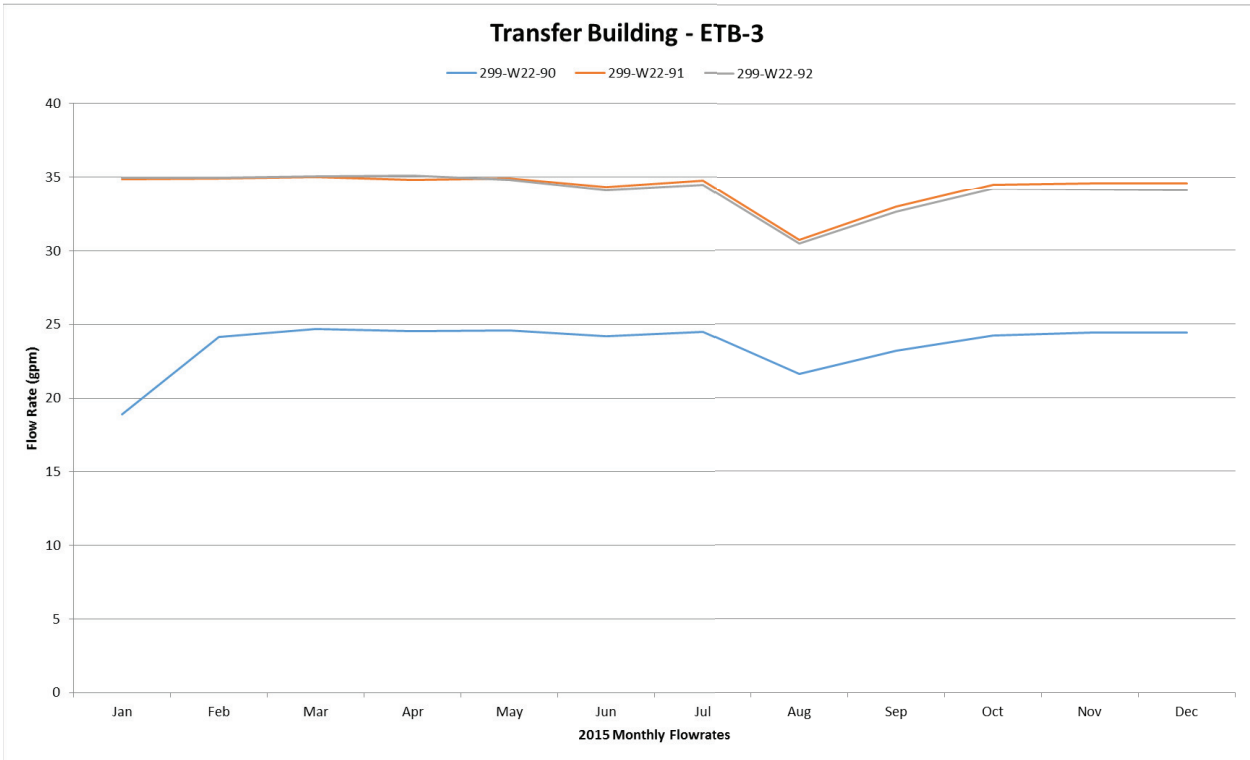
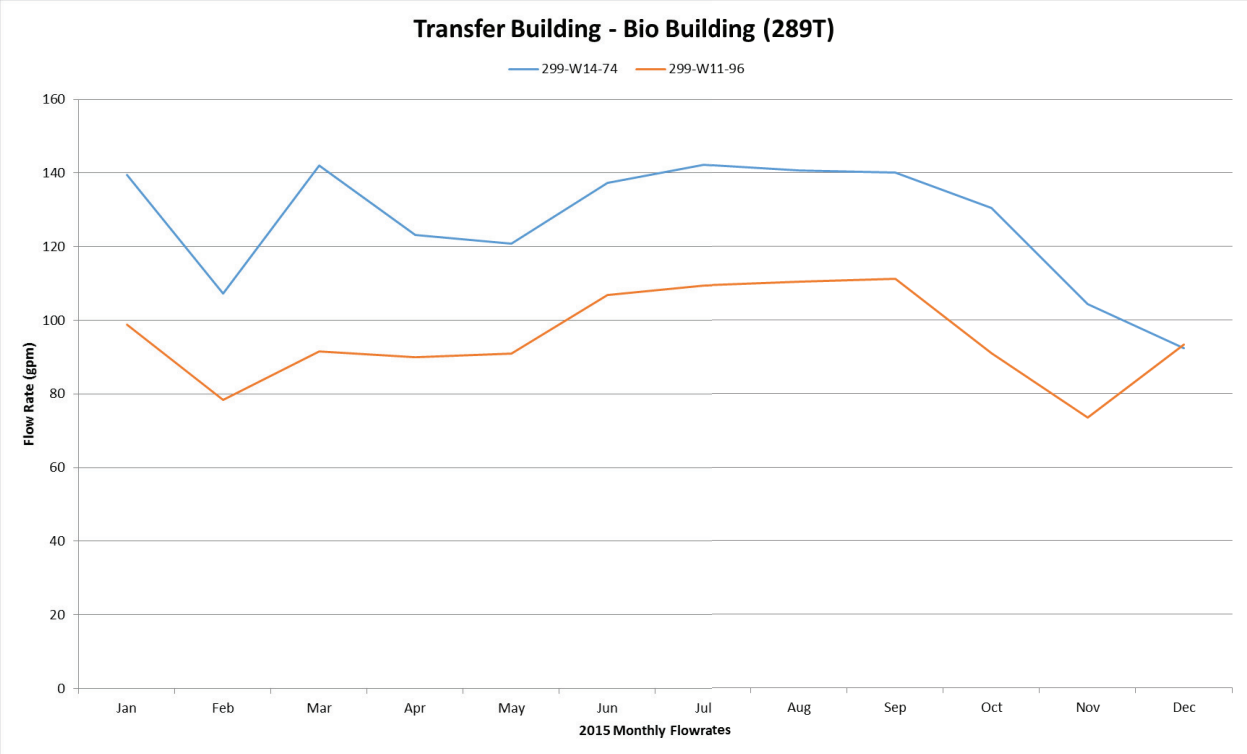


Figure 3-5. 200 West P&T Flow Rates for Extraction Wells with Radiological Contaminants, 2015



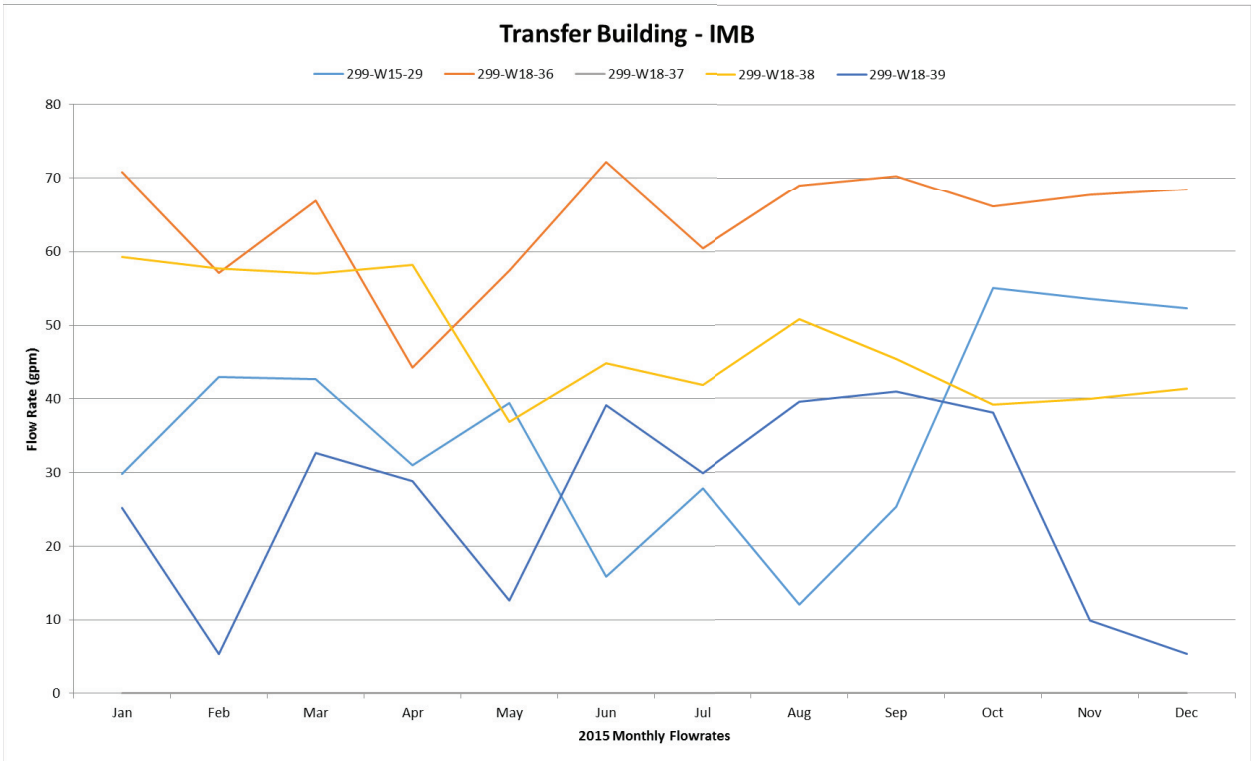
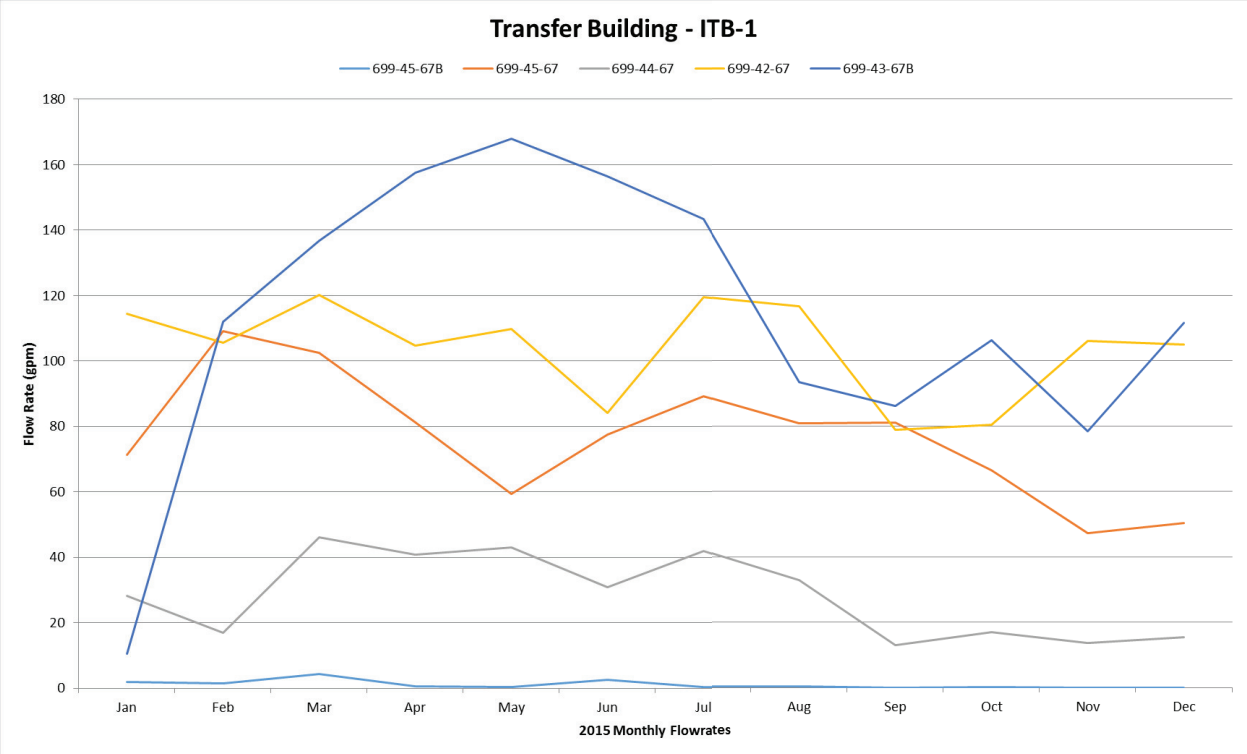


Figure 3-6. 200 West P&T Flow Rates for Extraction Wells without Radiological Contaminants (Top) and for Injection Wells (Bottom), 2015



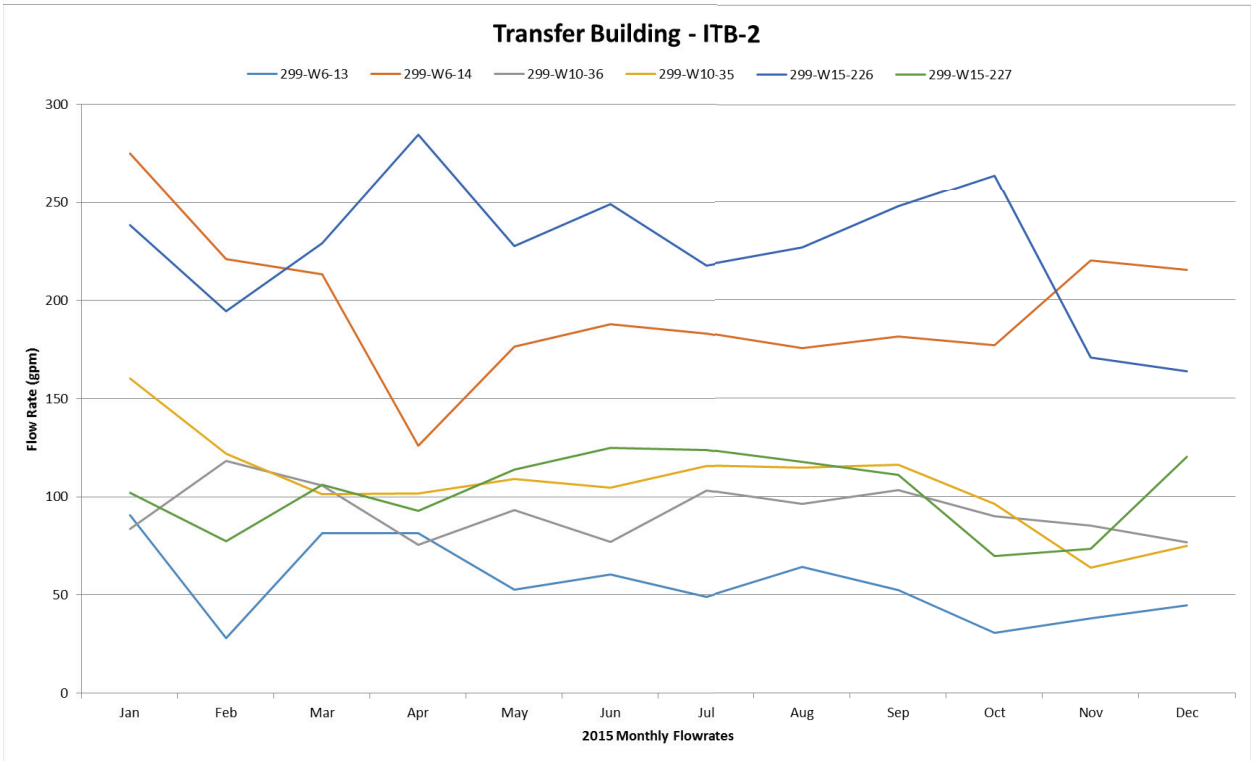


Figure 3-7. 200 West P&T Flow Rates for Injection Wells, 2015

Table 3-3. Extraction Well Average Concentration, 2015

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* (µg/L)
299-W15-225	YE-1	328	3.1	4.9	<0.44	40	42	0.6	1,036	0.8
299-W14-20	YE-2	1,225	29.5	32.7	<0.50	214	2,205	5.1	3,740	1.3
299-W14-73	YE-3	865	3.8	4.4	<0.40	81	102	4.9	1,065	0.9
299-W14-74	YE-4	984	20.0	21.5	<0.57	102	107	4.6	4,649	1.2
299-W12-2	YE-5	981	16.8	19.7	<0.67	70	41	2.6	304	1.1
299-W11-50	YE-6	548	59.0	63.1	<0.51	183	1,078	3.4	4,234	1.4
299-W11-90	YE-7	1,325	69.3	75.8	<0.51	247	365	10.7	13,175	1.7
299-W11-96	YE-8	1,194	60.8	67.2	0.63	275	297	6.0	8,180	1.5
299-W17-3	YE-9	231	2.5	2.9	<0.50	31	156	1.2	338	0.7
299-W17-2	YE-10	1,035	4.1	4.5	<0.49	98	77	6.7	<316	0.7
299-W19-111	YE-11	180	13.0	<1.5	<0.42	7	12	2.6	<312	0.8
299-W11-49	YE-12	805	1.9	2.4	<0.45	30	50	4.5	370	0.8
299-W11-97	YE-13	210	10.0	<1.5	<0.37	30	9	1.8	<320	1.6
299-W6-15	YE-14	855	97.8	108.0	0.87	185	268	4.0	7,026	1.5
299-W14-21	YE-15	423	1.4	3.3	<0.41	13	9	2.1	<325	1.0
299-W11-92	YE-16	645	4.7	6.6	<0.43	47	35	1.2	329	0.9
299-W5-1	YE-17	240	38.0	44.5	<0.61	216	346	0.6	1,175	1.6

Table 3-3. Extraction Well Average Concentration, 2015

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* (µg/L)
299-W12-3	YE-18	460	40.4	44.7	0.83	222	252	1.1	914	1.5
299-W12-4	YE-19	670	32.0	34.8	<0.45	31	9	2.6	321	1.2
299-W14-22	YE-20	343	7.2	8.7	<0.65	29	<9.5	1.9	<330	1.3
299-W22-90	YE-21	72	46.0	52.0	<0.41	29	818	0.3	1,279	2.7
299-W22-91	YE-22	66	38.5	42.3	<0.53	35	3,734	0.3	6,933	2.9
299-W22-92	YE-23	65	45.3	51.2	0.83	40	3,623	0.3	6,943	3.8
299-W19-113	YE-25	91	2.4	2.4	0.92	930	8,610	1.5	658	45.0
299-W19-114	YE-26	72	2.6	3.7	0.74	181	980	2.3	534	22.0
299-E33-268	YE-27	<0.1	9.2	9.2	2.50	408	6,930	<0.3	11,713	129.3

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

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

Table 3-4. Total Water Processed in 2015

Month	Water Processed (million L [million gal])	Flow Rate (L/min [gpm])
January	326.7 (86.3)	7,319 (1,933)
February	277.8 (73.4)	6,653 (1,758)
March	345.0 (88.5)	7,728 (1,983)
April	307.4 (81.2)	7,116 (1,880)
May	317.0 (83.7)	7,101 (1,875)
June	317.3 (83.8)	7,345 (1,940)
July	346.6 (91.6)	7,764 (2,052)
August	327.7 (86.6)	7,341 (1,940)
September	314.2 (83.0)	7,273 (1,921)
October	327.0 (86.4)	7,325 (1,935)
November	305.8 (80.8)	7,079 (1,870)
December	329.1 (86.9)	7,372 (1,947)
	Total: 3,831.5 (1,012.2)	**Average: 7,285 (1,919)**

Table 3-5. Central Treatment System Average Influent and Effluent Concentrations for 2015

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	650	<0.13	22.0	3.5	23.2	4.4	<0.30	<0.48	103	18	1,220	69	3.8	<0.3	5,675	2,390	1.3	1.1
February	625	<0.13	24.5	3.2	24.5	7.9	<0.32	<0.34	105	23	1,340	74	3.9	<0.3	5,540	2,440	1.2	1.2
March	300	<0.13	23.0	1.9	21.8	2.7	<0.26	<0.27	109	16	1,780	60	1.9	<0.3	6,840	2,750	1.3	1.0
April	500	<0.13	24.0	1.7	23.8	1.5	<0.20	<0.21	115	38	1,710	68	2.9	<0.3	6,620	2,950	1.2	1.0
May	510	<0.13	24.0	3.6	23.2	2.9	<0.23	<0.30	113	27	1,580	30	3.0	<0.3	7,370	2,485	1.2	1.0
June	560	<0.13	22.0	2.7	27.2	3.3	<0.12	<0.30	114	18	1,595	52	3.4	<0.3	6,680	2,770	1.2	1.0
July	430	<0.13	25.0	4.8	24.6	3.5	<0.60	<0.24	111	30	1,545	57	3.0	<0.3	6,250	2,560	1.2	1.1
August	555	<0.13	18.5	0.9	19.0	<1.5	<0.59	<0.26	106	28	1,480	70	3.3	<0.3	6,500	2,510	1.2	0.9
September	530	<0.13	23.0	3.2	23.0	3.3	<0.66	<0.20	111	29	1,530	76	3.6	<0.3	6,290	2,880	1.2	1.1
October	390	<0.13	19.0	2.6	19.0	<1.5	0.61	<0.28	141	6	768	67	2.6	<0.3	6,270	2,630	48	2.1
November	390	<0.13	19.0	3.9	19.0	2.9	<0.65	<0.23	133	31	947	62	2.5	<0.3	5,915	2,585	86	1.2
December	420	<0.13	28.0	8.2	30.0	5.8	0.62	<0.20	155	62[d]	783	67	2.7	<0.3	5,690	2,960	58	1.2

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 detection limit of 0.6 pCi/L.

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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3.1.2.6 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 3-4, a total of 3.8 billion L (1.1 billion gal) of groundwater was processed through the treatment system in 2015. Table 3-2 provides the total mass of COCs removed in 2015 by the 200 West P&T. Figures 3-8 through 3-10 illustrate the removal efficiency calculated by influent and effluent concentrations at the process facility. Figure 3-11 illustrates the cumulative mass removed by the system from July 2012, when operations of the 200 West P&T began, through December 2015.

3.2 200-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.

3.2.1 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.

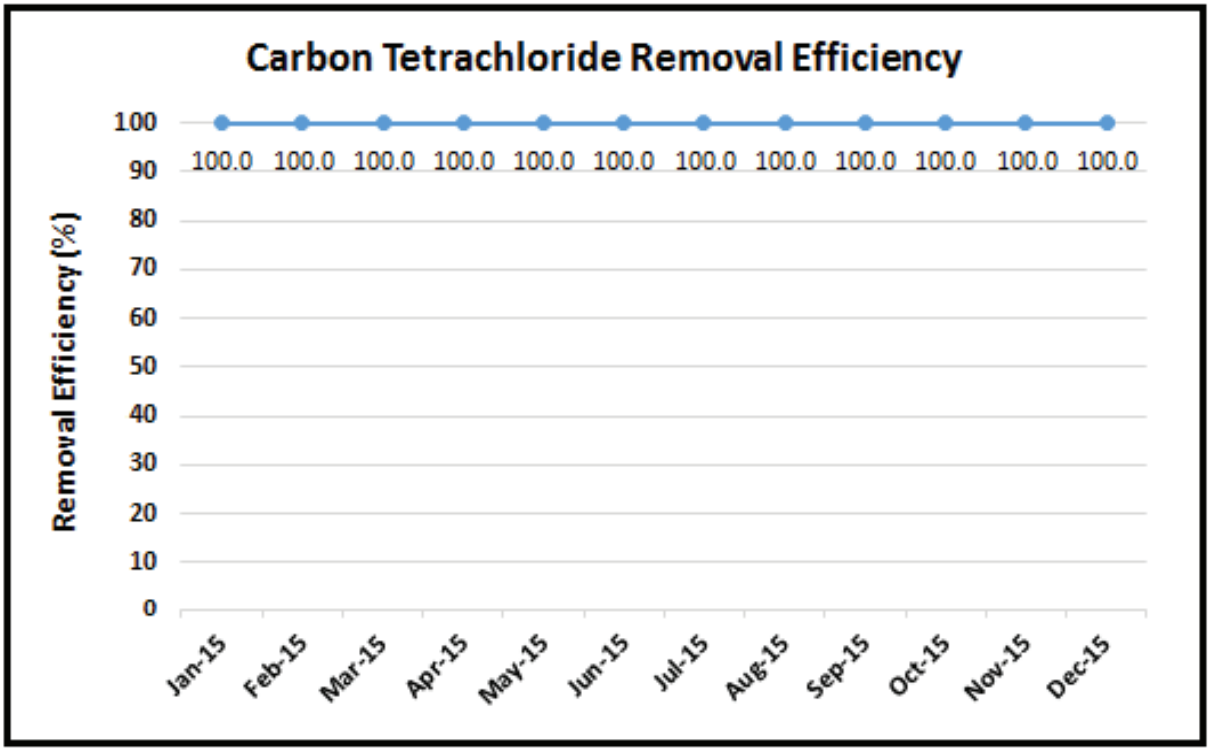
Groundwater level data obtained during 2015 comprise water levels obtained during synoptic water level campaigns, where water levels are obtained from a defined group of wells that cover a wide area throughout the OU and water levels obtained are from the AWLN, which comprises a smaller number of wells 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 2015 and present depictions and interpretations of these data.

3.2.1.1 Synoptic Survey Data

The synoptic water level event in the 200 West Area occurred during March 2015, 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 a total of 212 well locations over the entirety of fiscal year 2015 and during the synoptic event in March, 165 wells from the 200 West and 200 East Areas combined were used to prepare the depicted groundwater level maps.

3.2.1.2 Transducer Data

Throughout 2015, water levels were recorded using data loggers and transducers installed in approximately 30 monitoring wells throughout the 200-ZP-1 OU, plus additional monitoring wells that are instrumented with data loggers and pressure transducers as part of monitoring for the adjacent 200-UP-1 P&T remedies. In addition to the monitoring well data, water levels were recorded in the extraction and injection wells that were instrumented with data loggers and were actively operating during 2015, which varied in number throughout the year.



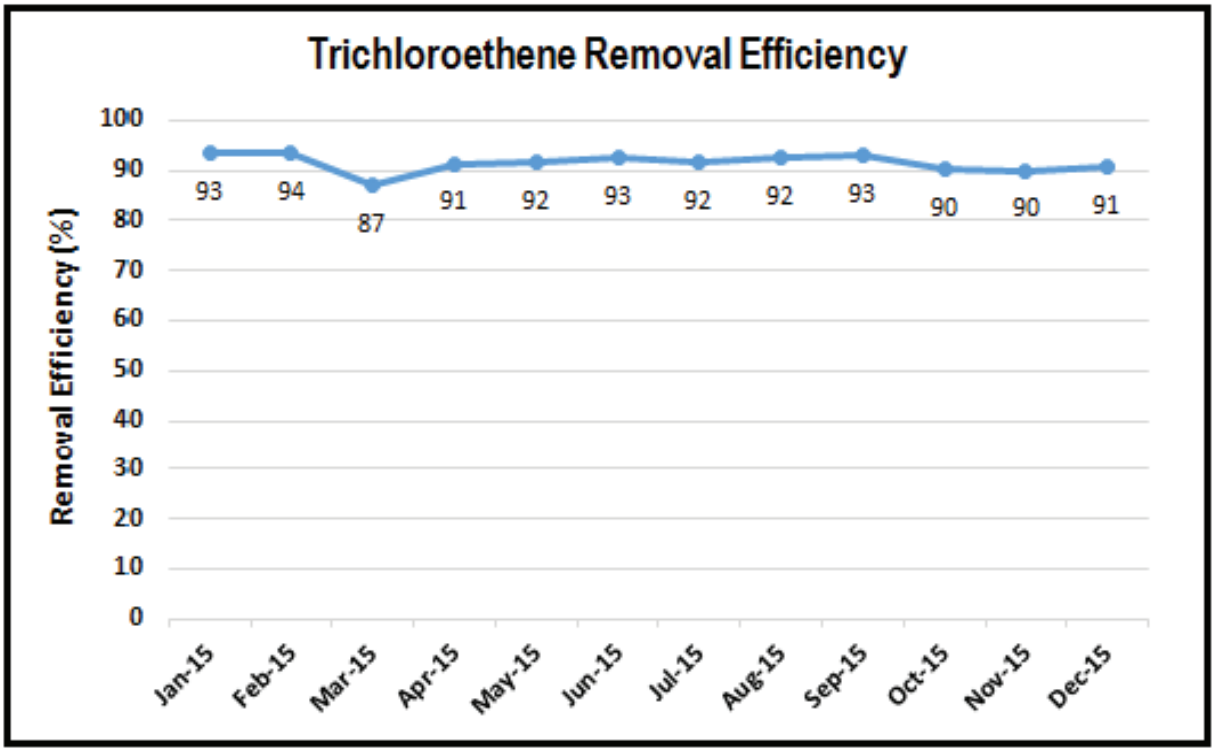
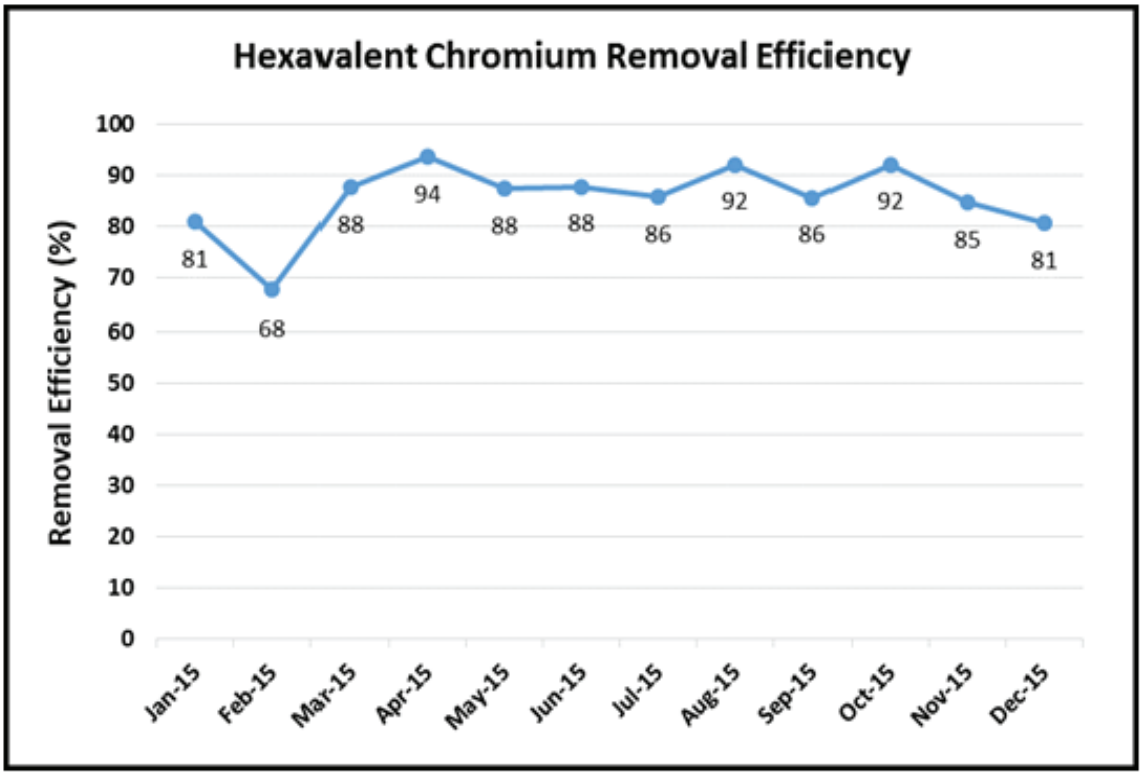


Figure 3-8. COC Removal Efficiency for Carbon Tetrachloride and Trichloroethene



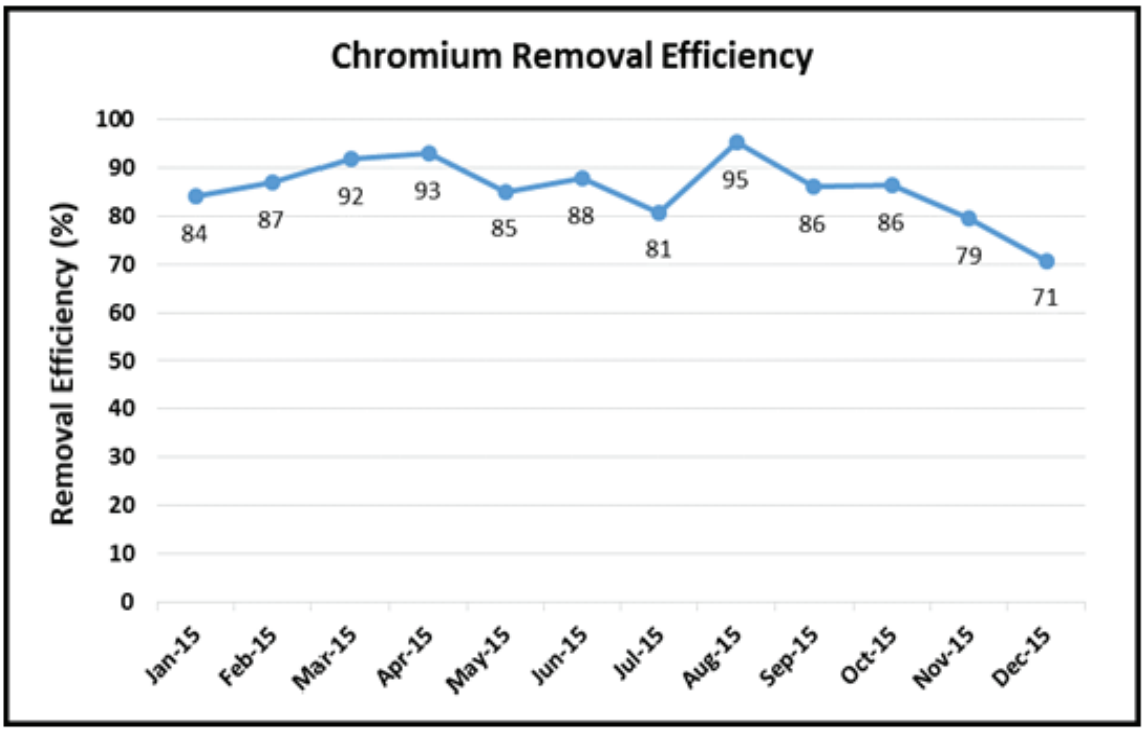
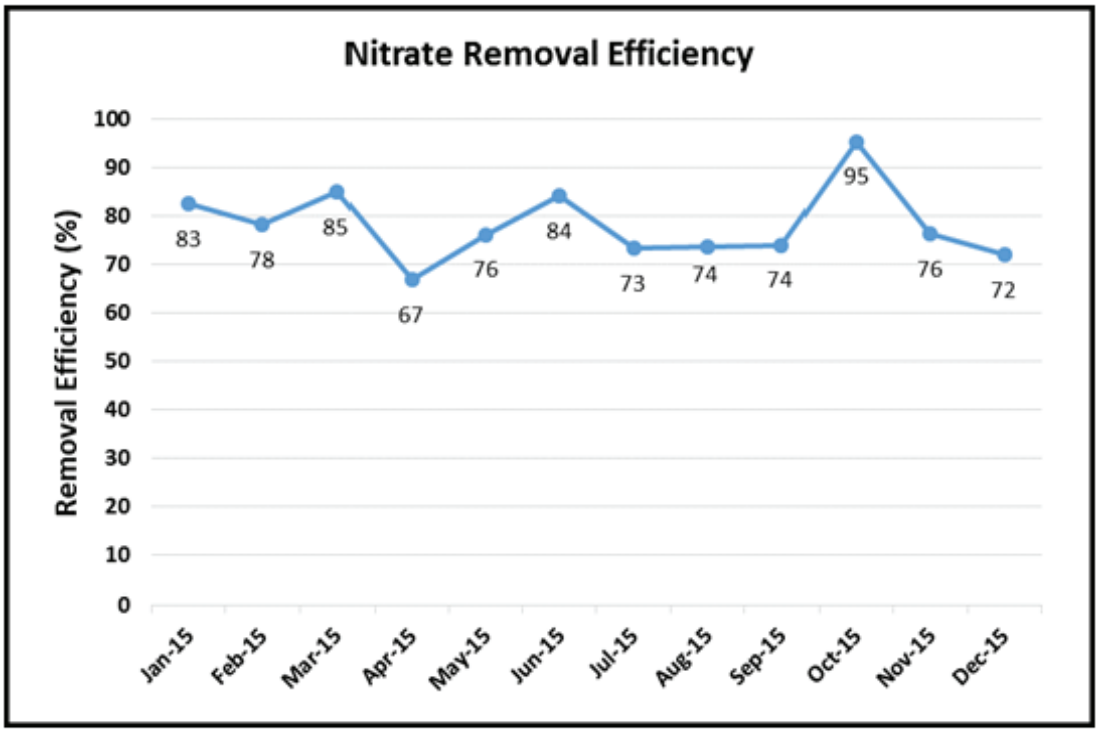


Figure 3-9. COC Removal Efficiency for Hexavalent Chromium and Total Chromium



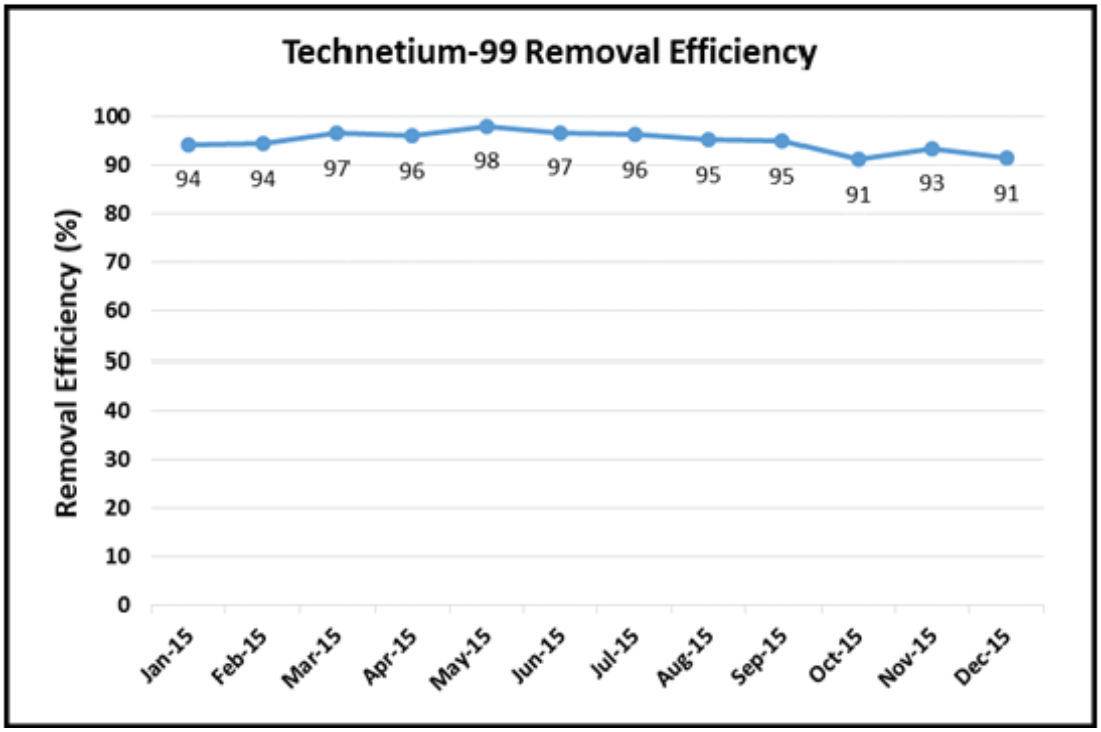
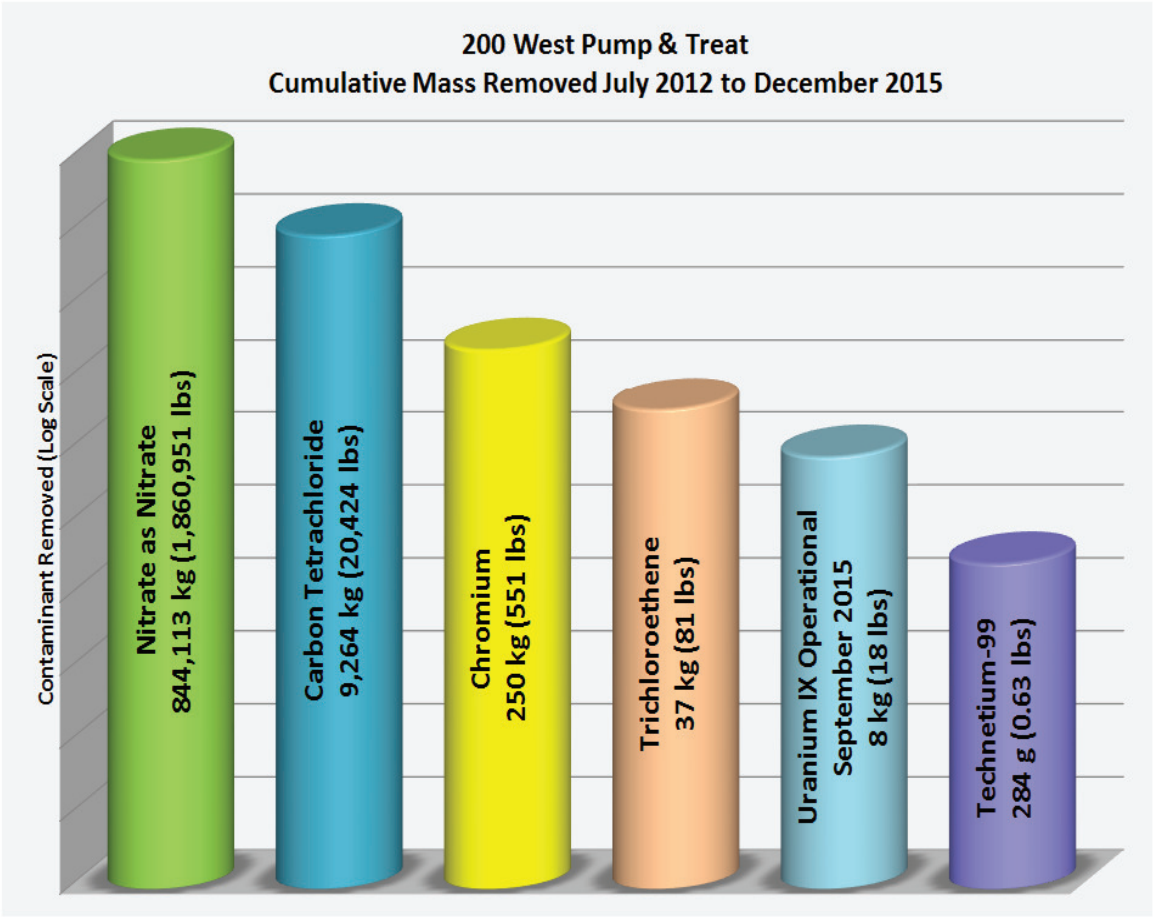


Figure 3-10. COC Removal Efficiency for Nitrate (as Nitrate) and Technetium-99



Note: Logarithmic scale used to include lesser contaminants.

Figure 3-11. Cumulative Contaminant Mass Removed by the 200 West P&T, 2012 through 2015

3.2.2 Analysis of Hydraulic Monitoring Data

The 200 West P&T average total throughput ranged between about 5,930 L/min (1,570 gpm) in November and up to 7,410 L/min (1,960 gpm) in July. 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 CY. Figure 3-12 depicts extraction and injection rates typical of operations during December 2015. Figure 3-13 depicts the current and planned status of the extraction and injection wells of the P&T component of the final 200-ZP-1 remedy, indicating wells that were installed and operating as of December 31, 2015, and the schedule for completion of the remaining wells.

3.2.2.1 Evaluation of the Water Table

Extraction and injection rates for CY 2015 that were used for water level mapping and hydraulic containment analyses described in this subsection are depicted in Figures 3-4 through 3-7. Figures 3-14 through 3-16 present water level hydrographs for selected monitoring wells in the AWLN located near the 200-ZP-1 OU groundwater extraction and injection wells. These figures illustrate the changes in groundwater elevations in response to changing pumping patterns throughout the 200-ZP-1 OU. Measured changes in groundwater levels during CY 2015 are less dramatic than during recent years, as groundwater extraction and treated water reinjection in 200-ZP-1 have approached design rates and adjustments in rates have been smaller than in recent years.

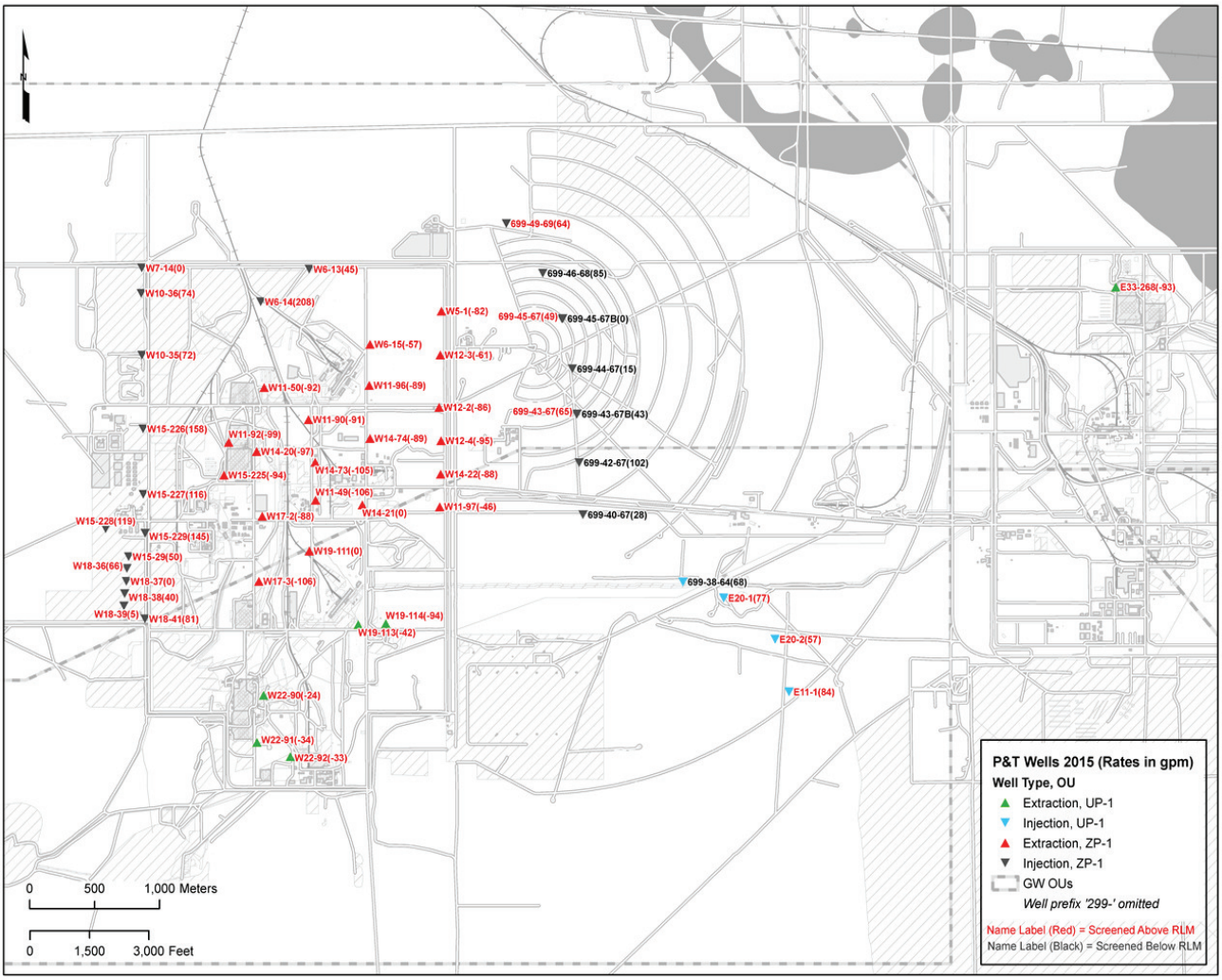


Figure 3-12. Groundwater Extraction and Injection Rates for the 200 West P&T, December 2015

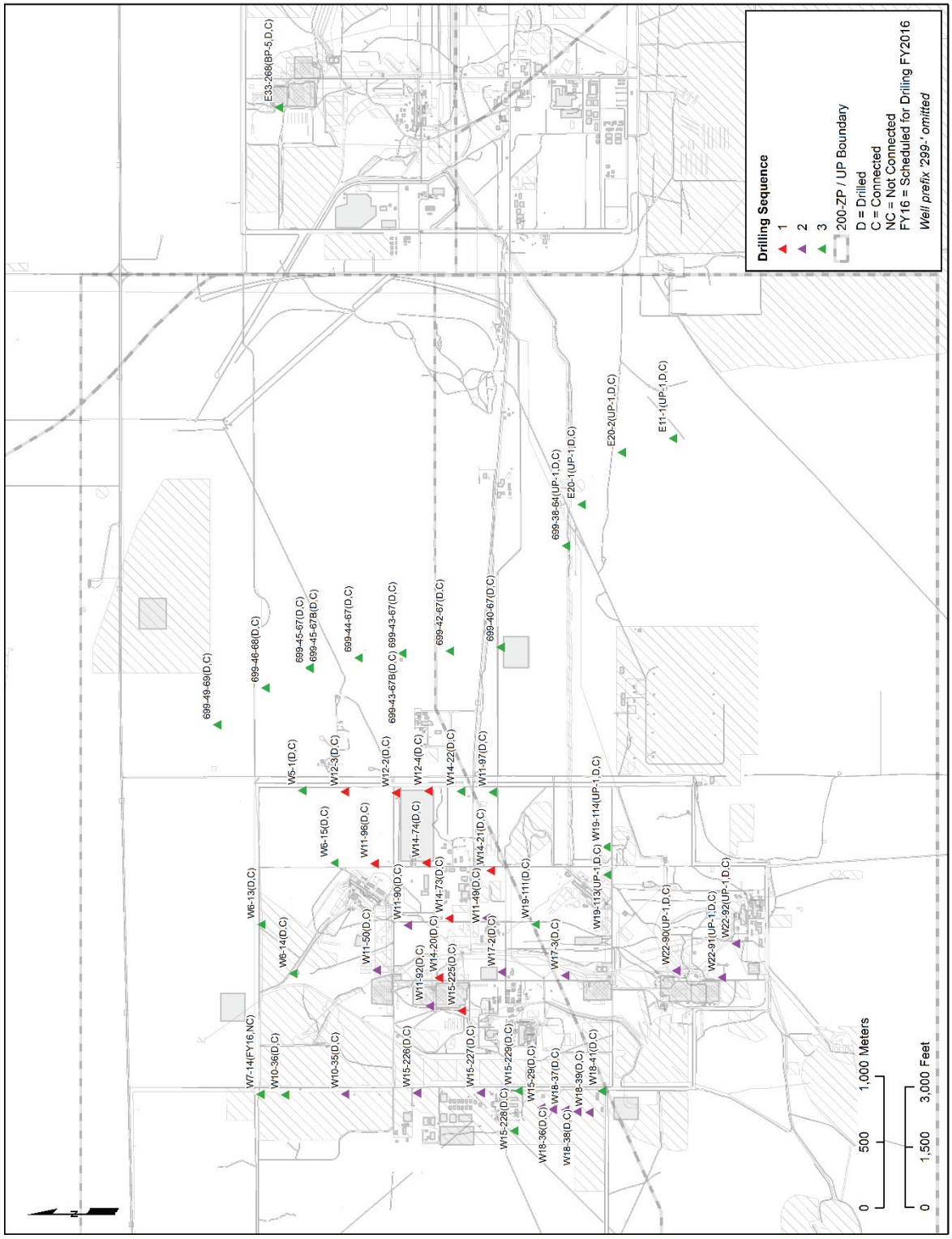
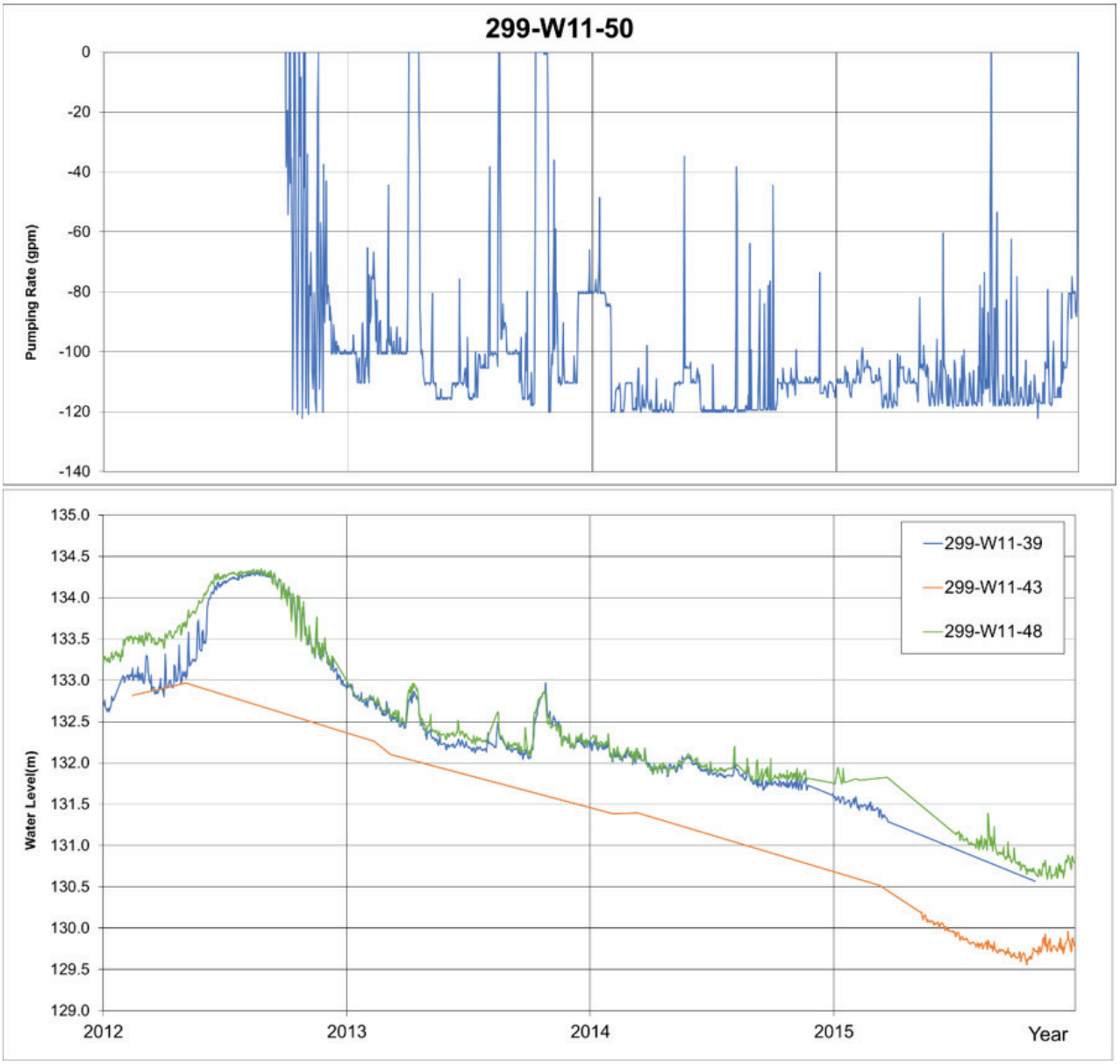
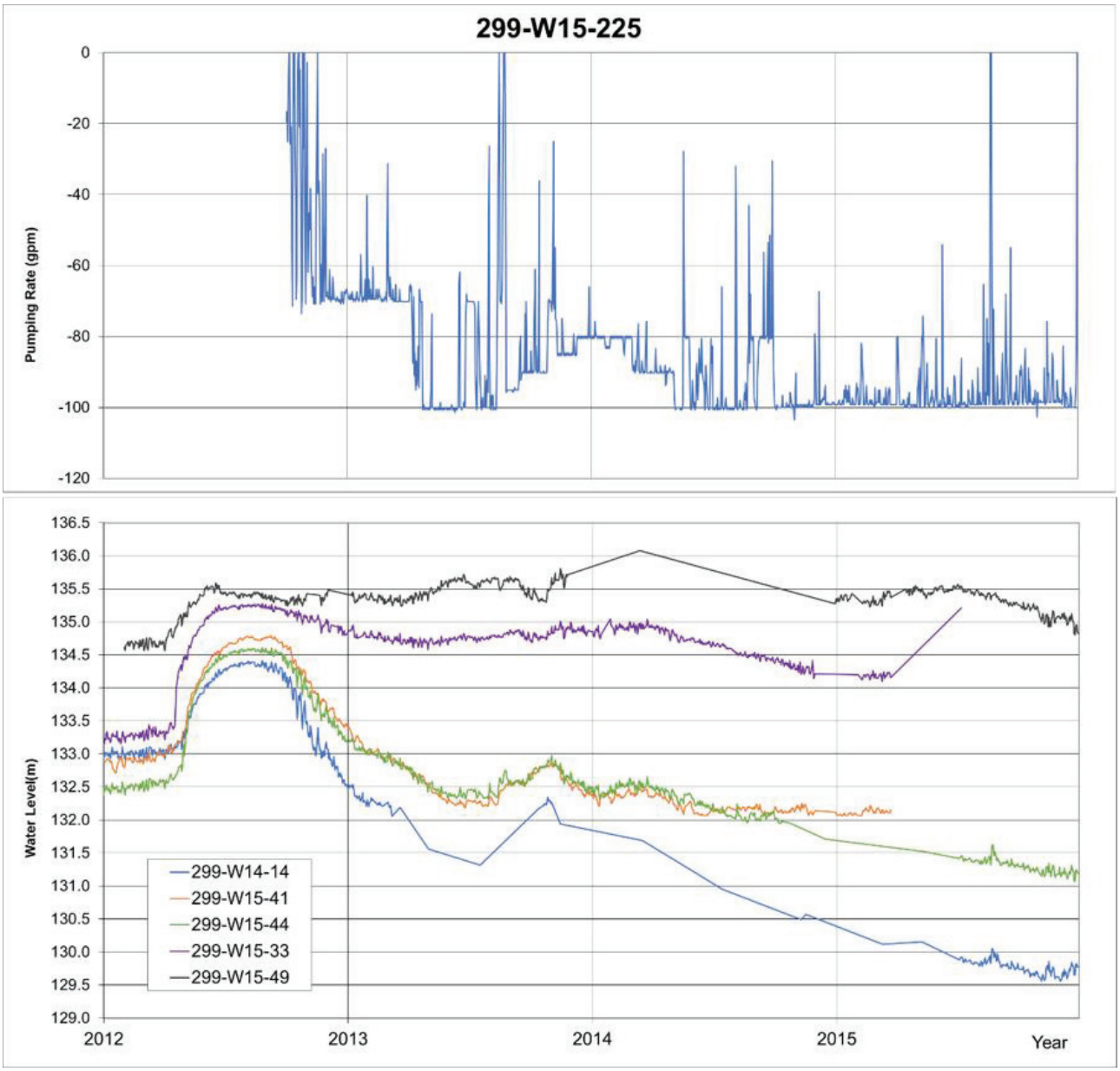


Figure 3-13. Status of Groundwater Extraction and Injection Wells for the 200 West P&T



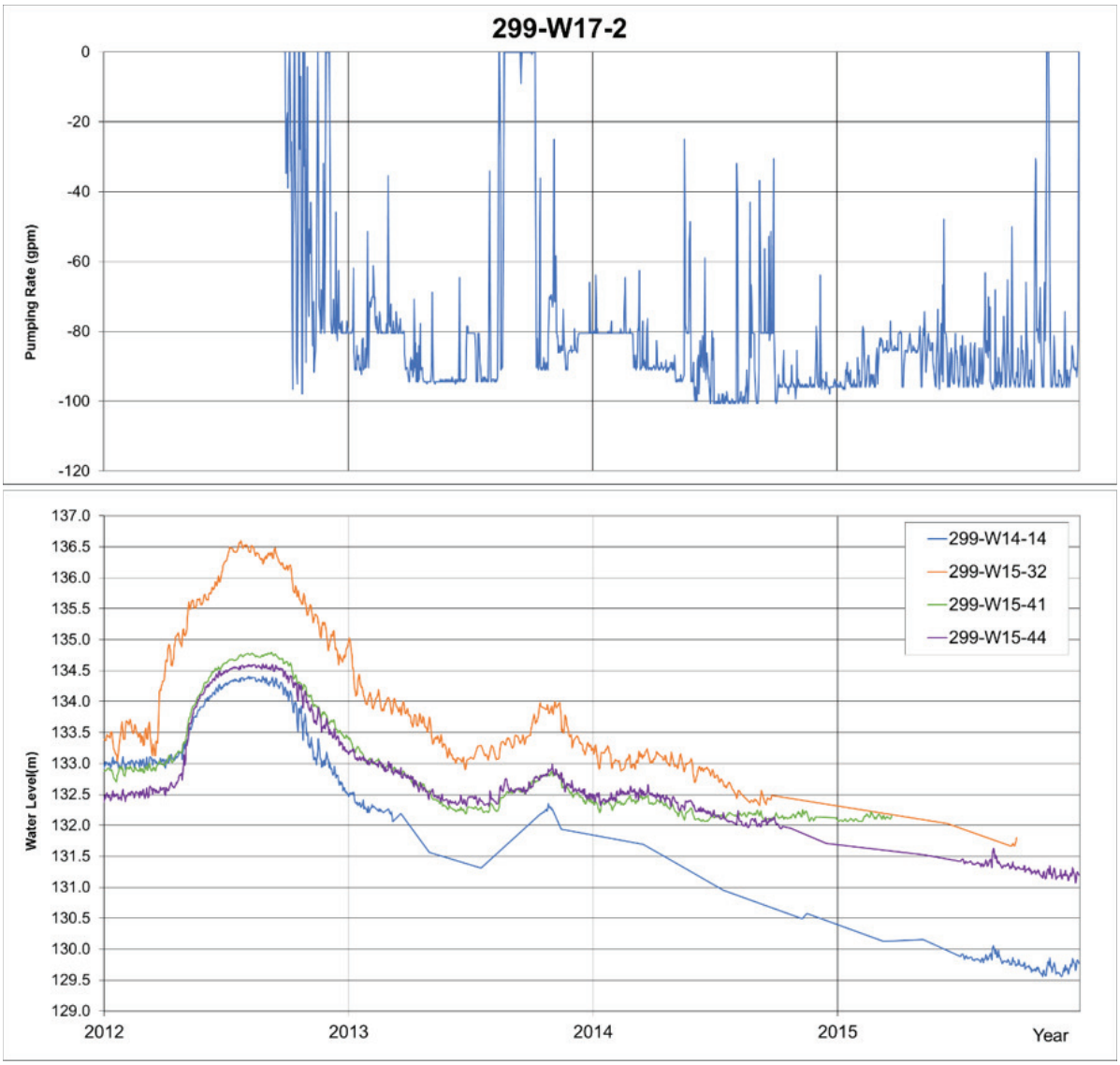
Note: Negative flow rate values indicate extraction out of the aquifer, and positive flow rate values indicate injection into the aquifer.

Figure 3-14. Water Level Hydrographs for Selected Monitoring Wells Located near Groundwater Extraction and Injection Wells



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

Figure 3-15. Water Level Hydrographs for Selected Monitoring Wells Located near Groundwater Extraction and Injection Wells



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

Figure 3-16. Water Level Hydrographs for Selected Monitoring Wells Located near Groundwater Extraction and Injection Wells

Groundwater levels were evaluated in two dimensions by interpolating water level data obtained during December 2015. The difference between the interpolated water levels obtained using data from December 2015 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, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*, with a combination of the manual water level data, AWLN data, and contemporaneous groundwater extraction and injection rates at operating P&T remedy system wells.

Figure 3-17 depicts groundwater elevation contours computed using water level mapping. The first set of contours (Figure 3-17 inset a) depicts the water table during June 2012, when no P&T remedy was operating in the 200 West Area (DOE/RL-2013-14, *Calendar Year 2012 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat*, and ECF-200ZP1-13-0006, *Description of Groundwater Modeling Calculations for the Calendar Year 2012 (CY2012) 200 Areas Pump-and-Treat*, provide details on the original preparation of these contours). The second set of contours (Figure 3-17, inset b) depicts the water table during December 2015 with the 200 West P&T and 200-UP-1 remedies operating in the 200 West Area. Figure 3-17 was prepared by interpolating water level data obtained in 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 3-17 (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 3-17 (inset b) shows a well-defined area of convergent hydraulic gradients centered on the extraction wells.

Figure 3-18 presents two depictions of the change in groundwater level as computed using the water level mapping method for data above the RLM between June 2012 (when no remedy was operating) and December 2015. 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. 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, Figure 3-18 (inset a) presents the simple difference between the June 2012 and December 2015 water level contours (i.e., unadjusted change), while Figure 3-18 (inset b) presents the difference between the June 2012 and December 2015 water level contours plus the estimated area-wide head change of about 0.875 m (2.87 ft) from June 2012 to December 2015 due to the cessation of historical operational discharges (i.e., adjusted change). Thus, Figure 3-18 (inset b) approximates the change in groundwater levels that is due solely to the operation of the 200 West and S-SX P&T systems.

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 3-18, which only reflects changes in groundwater levels above the RLM.

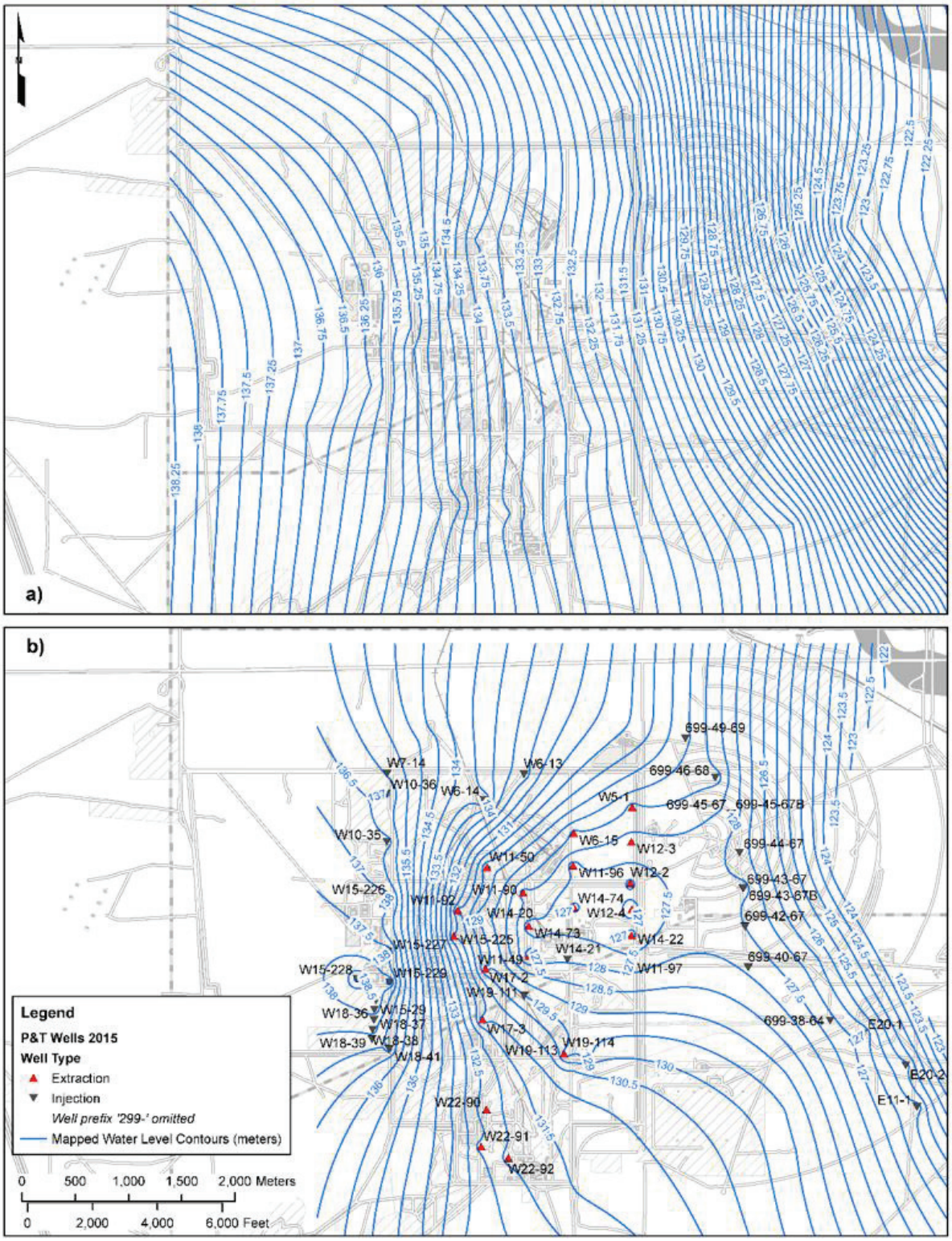


Figure 3-17. Groundwater Elevation Contours Computed Using Water Level Mapping: (a) above RLM during June 2012; (b) above RLM during December 2015

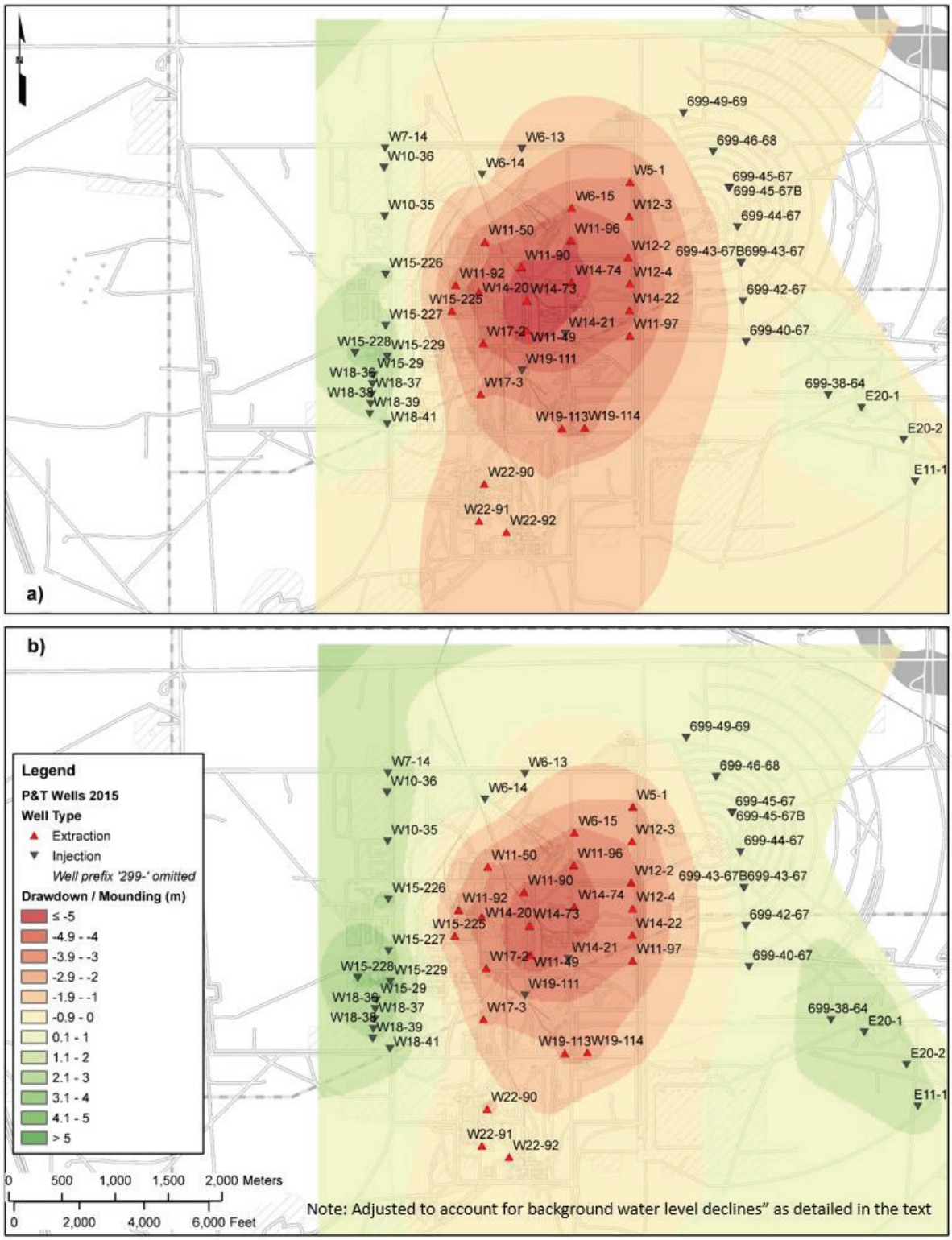


Figure 3-18. Drawdown and Mounding Computed Using Water Level Mapping above RLM between June 2012 and December 2015: (a) Unadjusted; (b) Adjusted Calculation

Figure 3-19 depicts the estimated extent of hydraulic containment developed by groundwater extraction and reinjection at the 200 West P&T during December 2015, 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 3-17 (inset b) and using the techniques detailed in SGW-42305. Figure 3-19 illustrates the combined extent of hydraulic containment rather than the extent of containment developed by individual wells, since 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 3-19 is smaller than that which will ultimately be developed by the final remedy operating at design rate of 7,571 L/min (2,000 gpm).

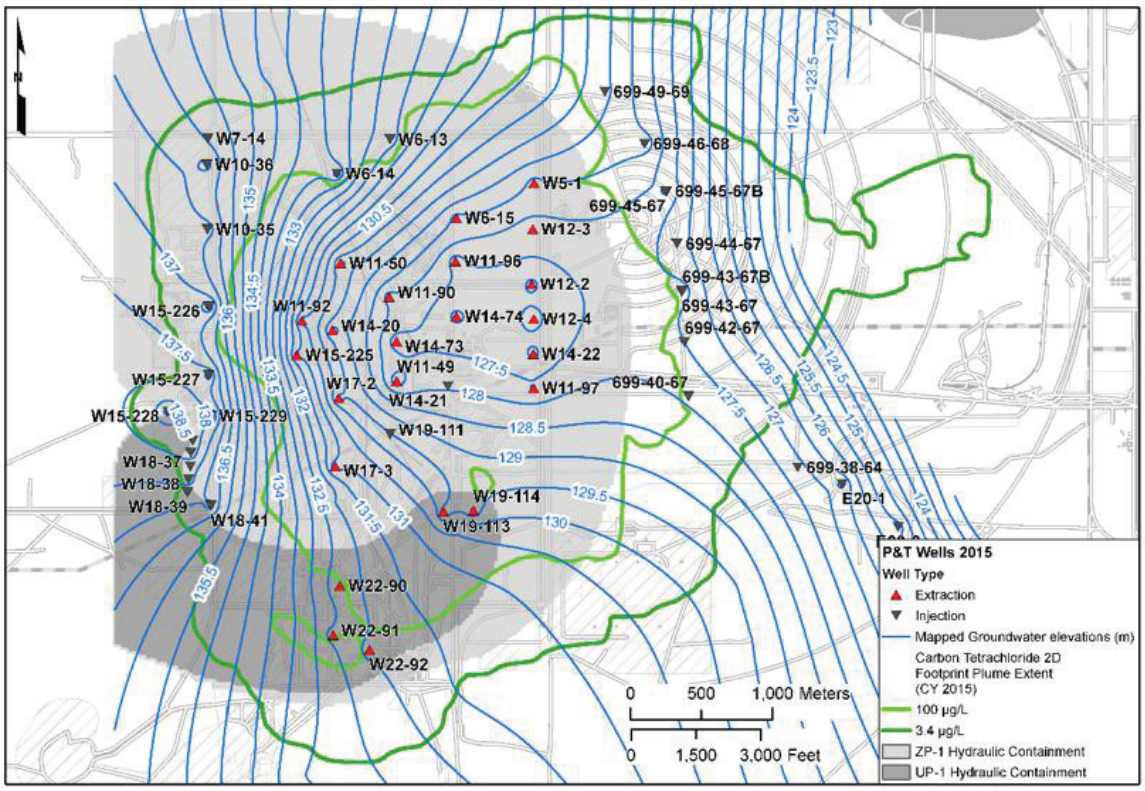


Figure 3-19. Extent of Hydraulic Containment Computed for December 2015 Using Water Level Mapping above RLM

3.2.2.2 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 respect 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 and others:

- 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 Model (CP Model) are presented in later subsections for comparison with the interpolated water level and hydraulic containment maps.

3.2.2.3 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, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*. 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. This is expected to be most pronounced in areas adjacent to the 200-ZP-1 OU extraction wells.

SGW-50907 predicted that the following 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):

- 299-W10-4*
- 299-W11-3*
- 299-W11-6*
- 299-W15-3
- 299-W22-20*
- 299-W22-48*
- 299-W6-12
- 699-32-77
- 699-48-77D
- 299-W11-10*
- 299-W11-37*
- 299-W14-6*
- 299-W18-30*
- 299-W22-26*
- 299-W22-50*
- 299-W7-4
- 699-48-77A*
- 699-50-59

At the time this report was prepared (early in CY 2016), wells marked with an asterisk had become sample dry.

The following additional wells were projected to become sample dry during the second year of operation (i.e., CY 2013):

- 299-W10-5*
- 299-W10-8*
- 299-W19-35*
- 299-W22-44*
- 299-W22-49

At the time of report preparation (early in CY 2016), wells in the preceding lists marked with an asterisk (plus 299-W15-41) had become sample dry. Of the wells that were sample dry at the time the study reported in SGW-50907 was completed (in CY 2011) but were still in use for water level measurements, the following wells had become totally dry or were no longer in use for water levels:

- 299-W10-22
- 299-W18-28
- 299-W11-7
- 299-W19-37
- 699-35-70
- 699-38-70

For some monitoring wells, the status 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 of a tank farm and is currently inaccessible for routine sampling. 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, 299-W8-1, which was sample dry during CY 2012, now contains sufficient water to be sampled.

Declines in groundwater levels could 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 2015, 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., well screen fouling) will increase over time.

3.3 200-ZP-1 Contaminant Monitoring

DOE will monitor contaminants in groundwater over the lifetime of the remedial action to evaluate performance and optimize effectiveness (DOE/RL-2009-115). Laboratory methods used to analyze the samples must have detection limits at or below the final cleanup levels defined in Table 3-1 in order to assess the success of the remedy.

3.3.1 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 3-20 through 3-35) are represented by three categories:

- High-concentration zone of carbon tetrachloride contamination close to ponds, cribs, and trenches that were used to dispose liquid wastes (data do not indicate a continuing source)
- Larger dispersed or low concentration zone of carbon tetrachloride contamination that has migrated from the discharge locations or that 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

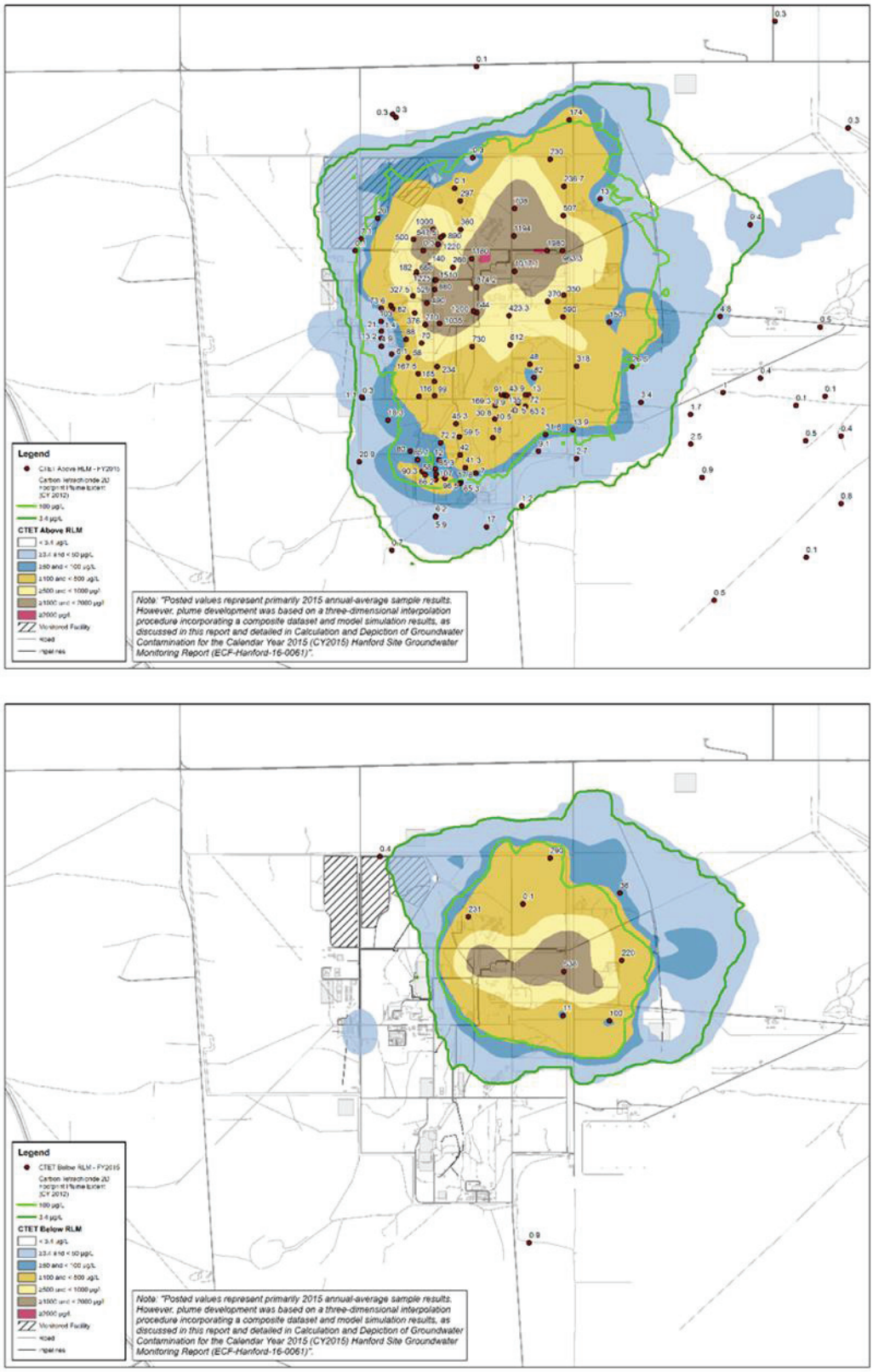
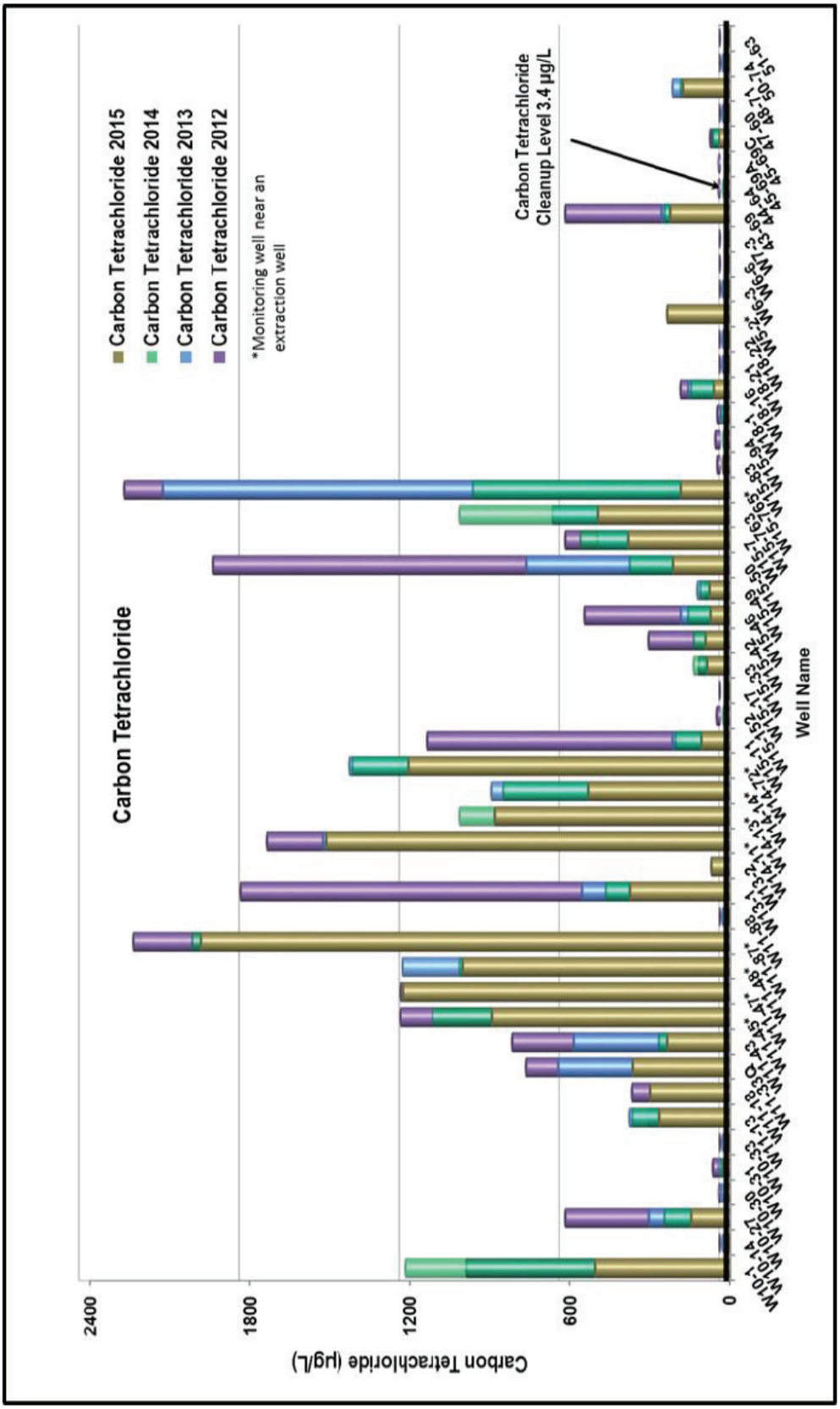
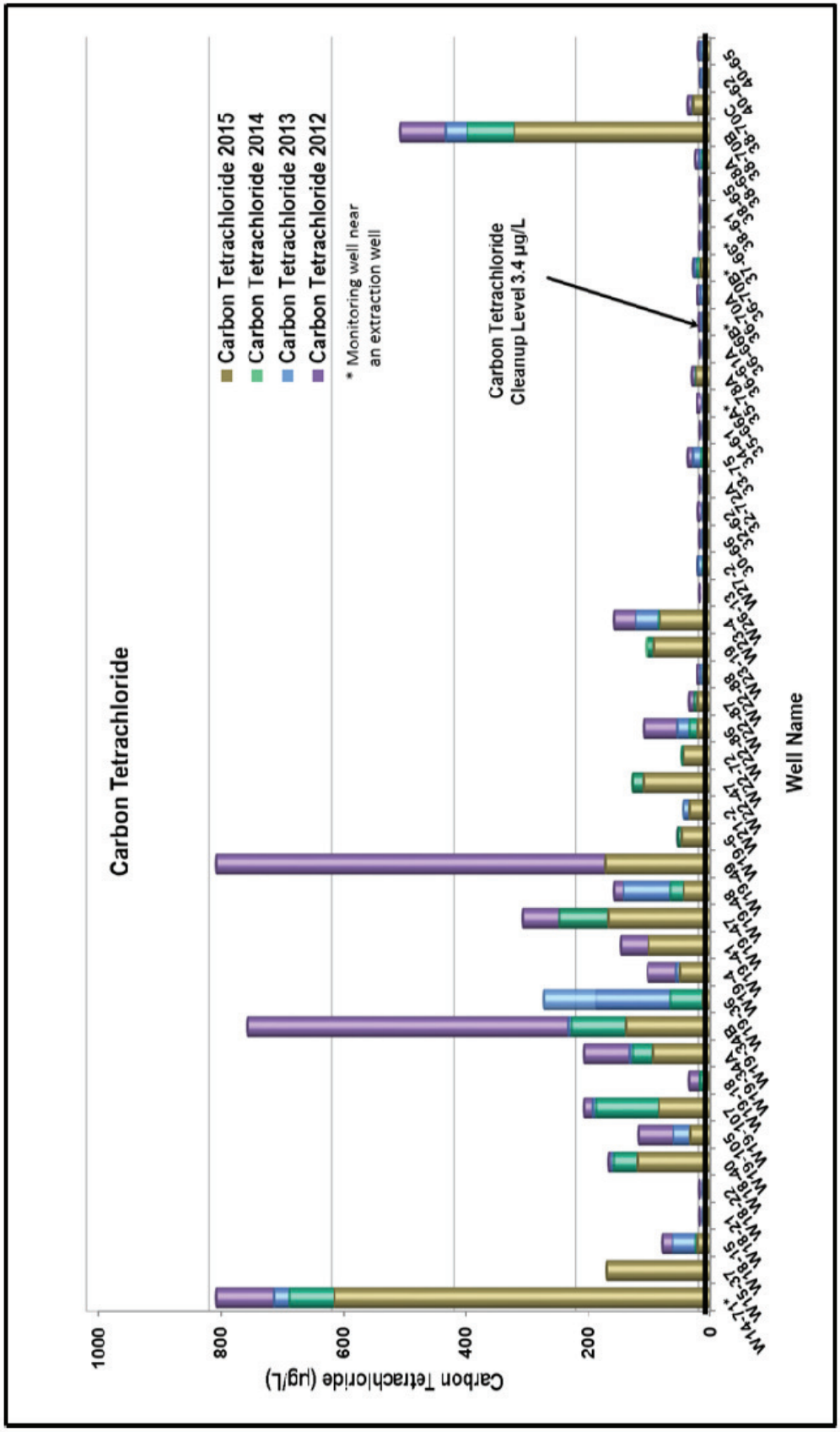


Figure 3-20. Contaminant Plume Map for Carbon Tetrachloride, 2015 (a) Above Ringold Lower Mud and (b) Below Ringold Lower Mud



Note: Wells with increasing concentrations in 2015 are shown as solid brown bars in the figure.

Figure 3-21. Comparison of Carbon Tetrachloride Concentrations in 200-ZP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015



Note: Wells with increasing concentrations in 2015 are shown as solid brown bars in the figure.

Figure 3-22. Comparison of Carbon Tetrachloride Concentrations in 200-UP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015

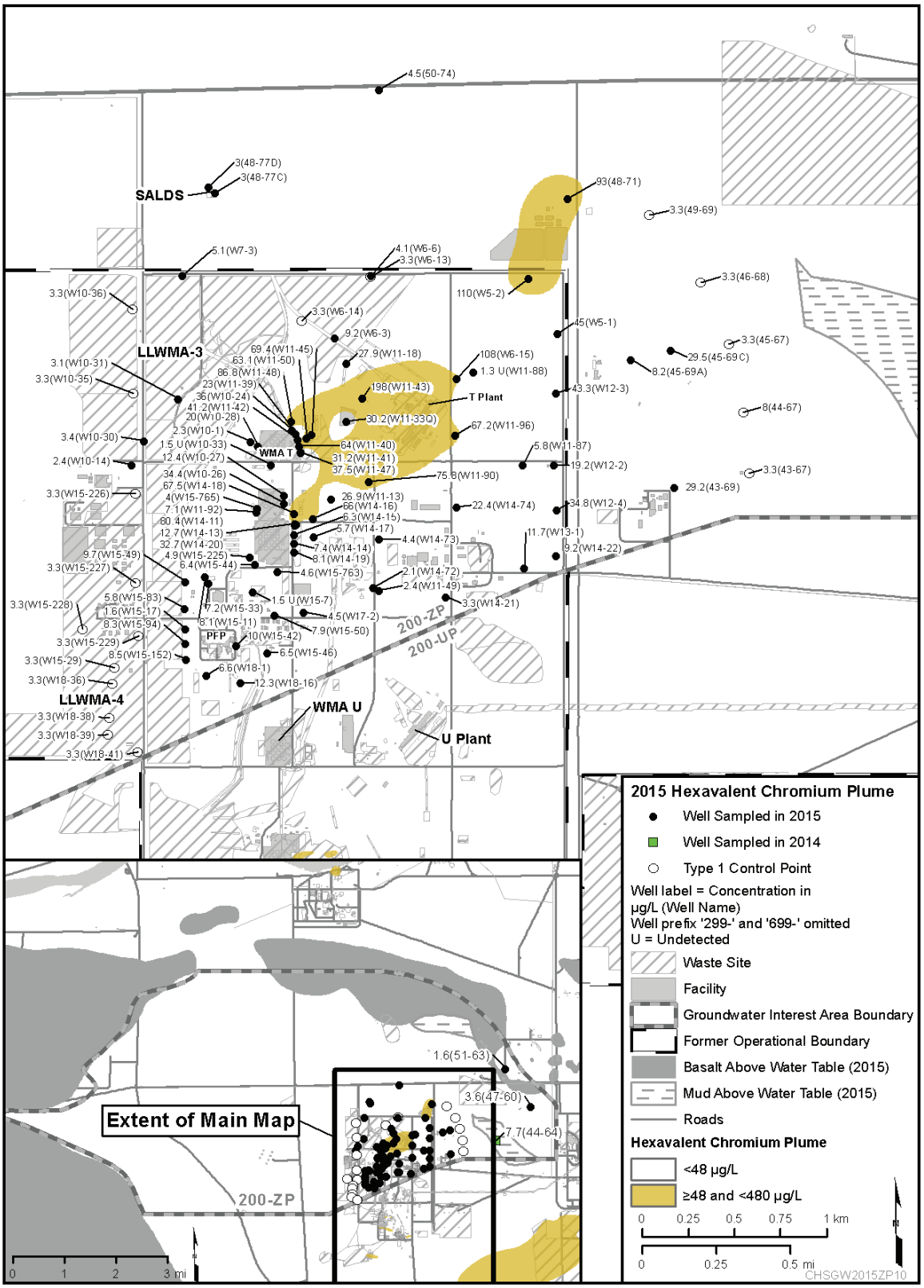
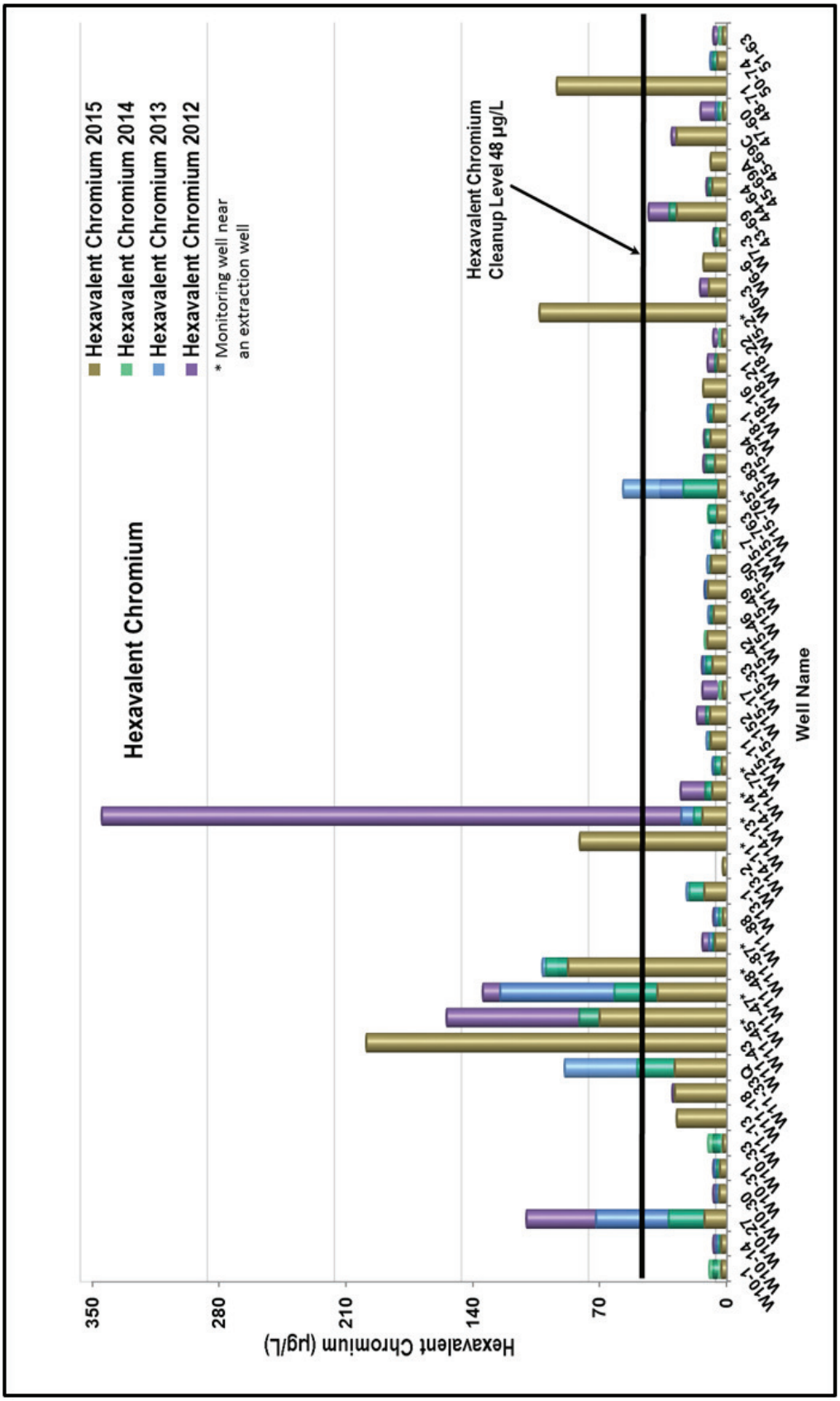


Figure 3-23. Contaminant Plume Map for Chromium, 2015



Note: Wells with increasing concentrations in 2015 are shown as solid brown bars in the figure.

Figure 3-24. Comparison of Hexavalent Chromium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015

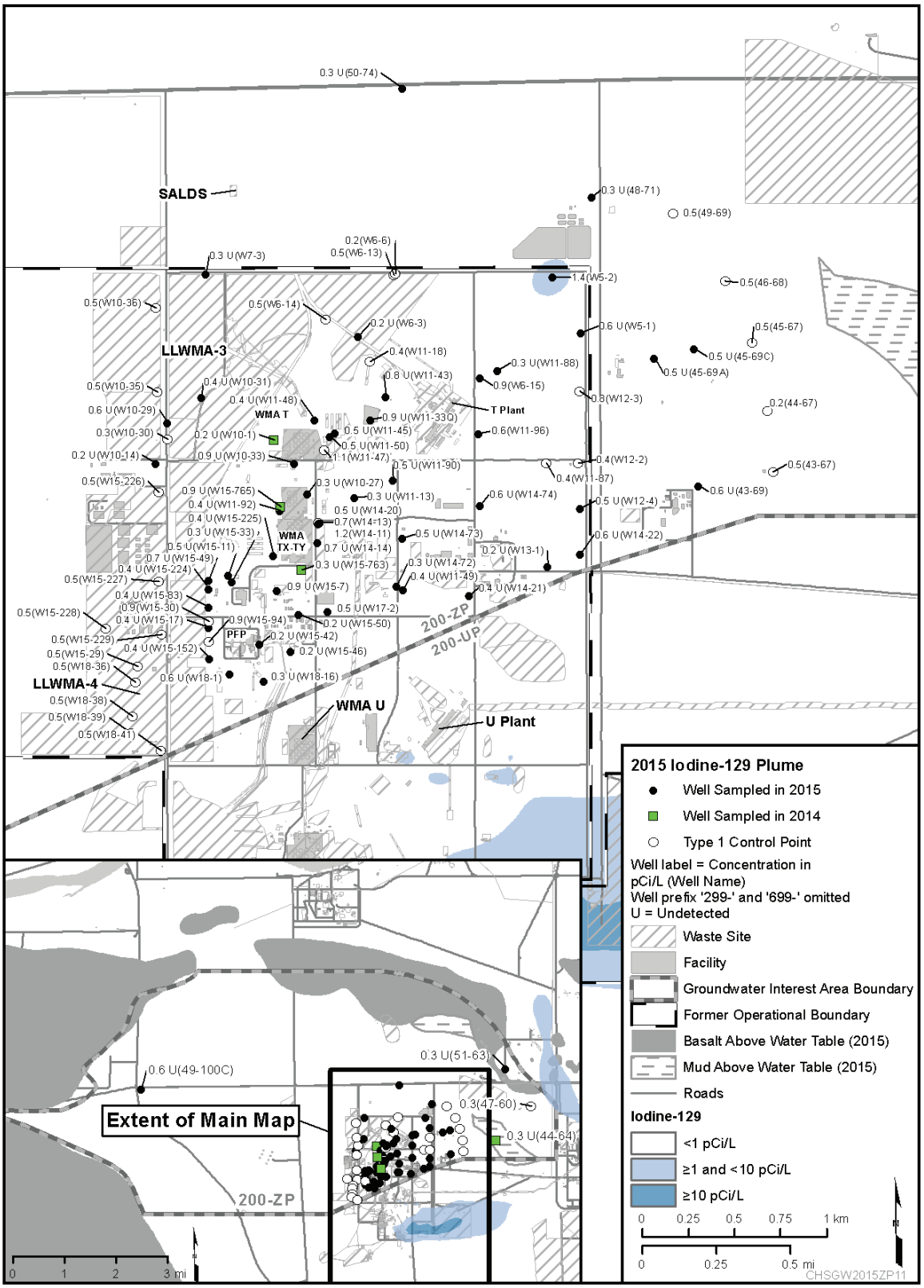
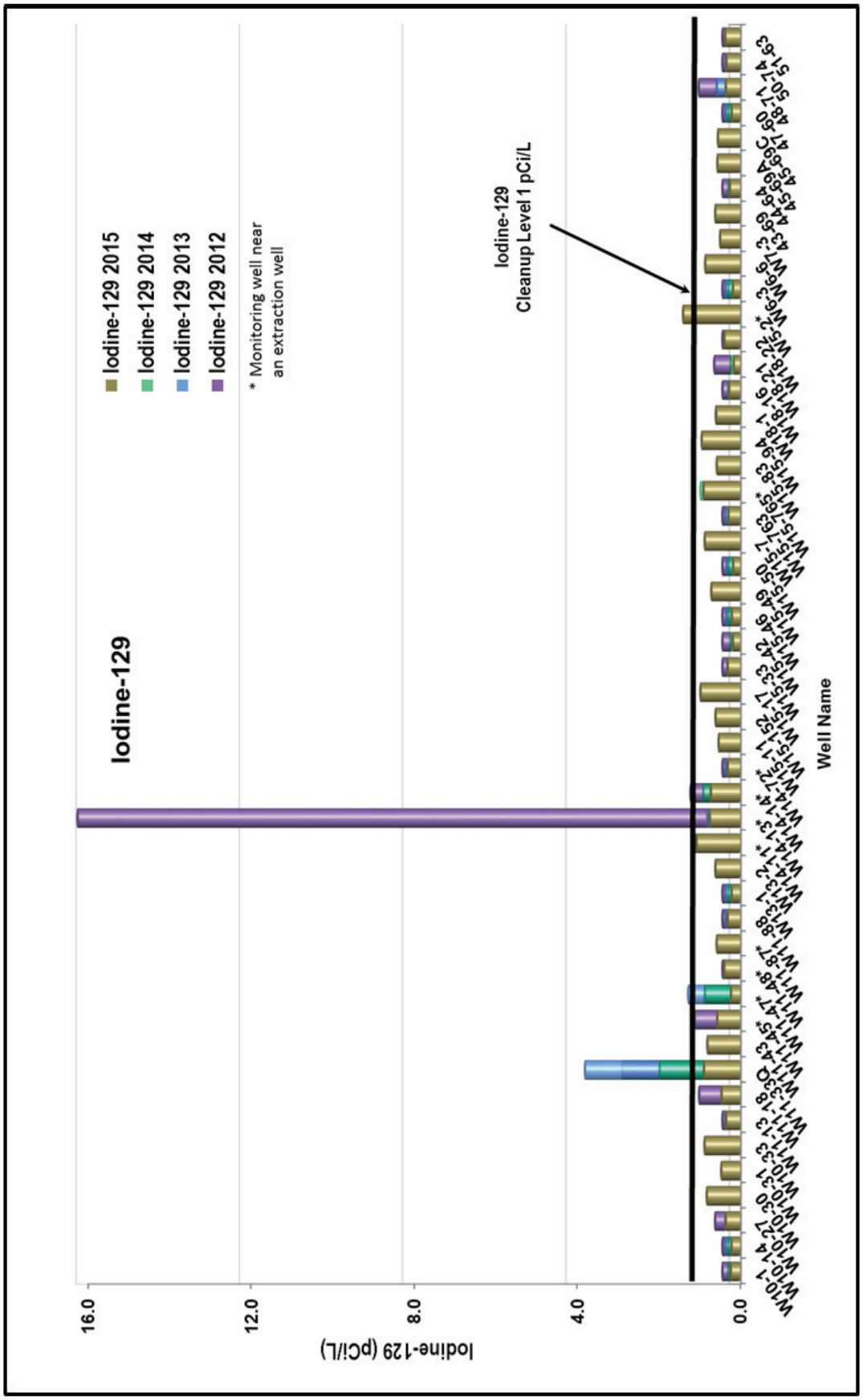


Figure 3-25. Contaminant Plume Map for Iodine-129, 2015



Note: Wells with increasing concentrations in 2015 are shown as solid brown bars in the figure.

Figure 3-26. Comparison of Iodine-129 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015

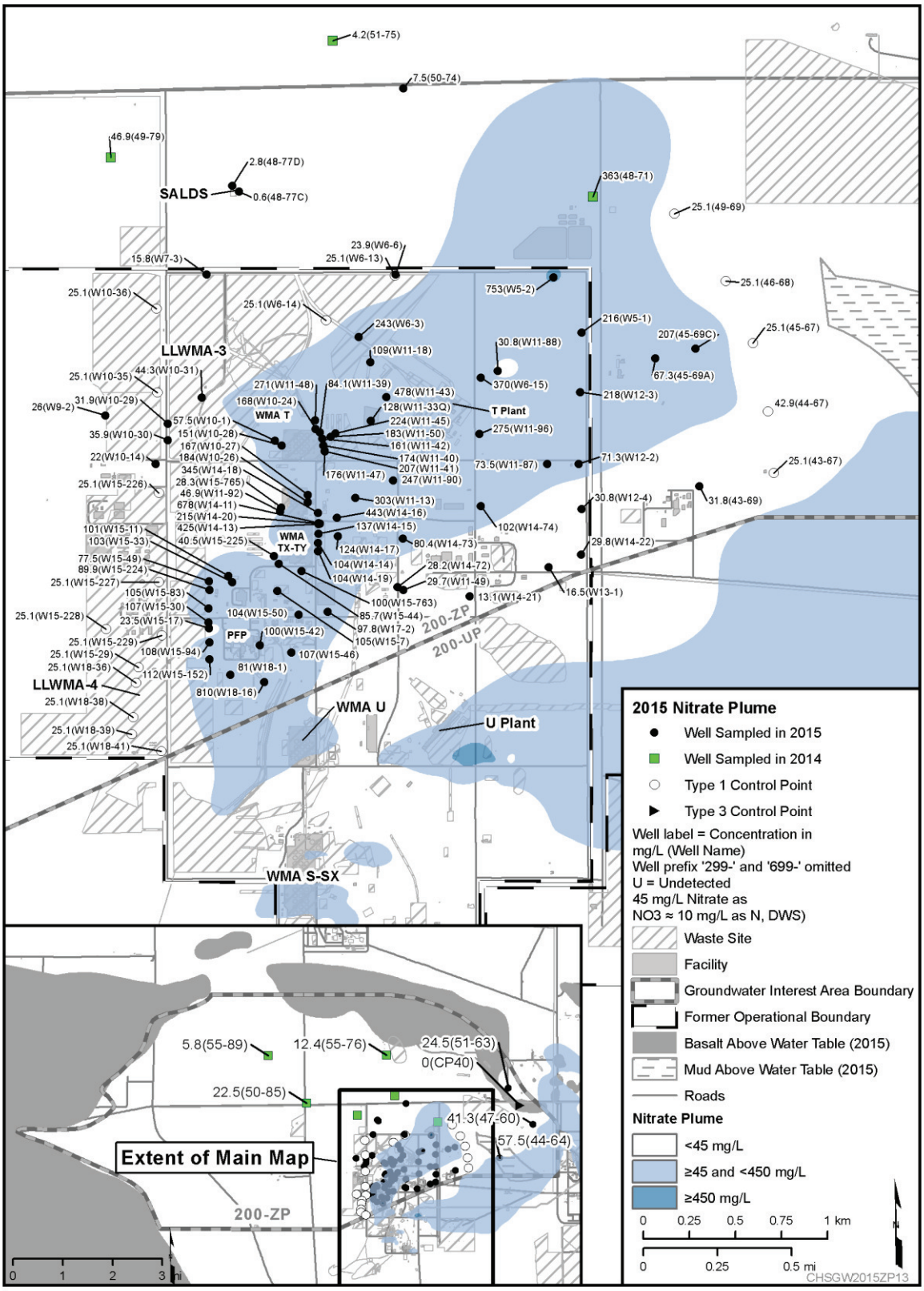
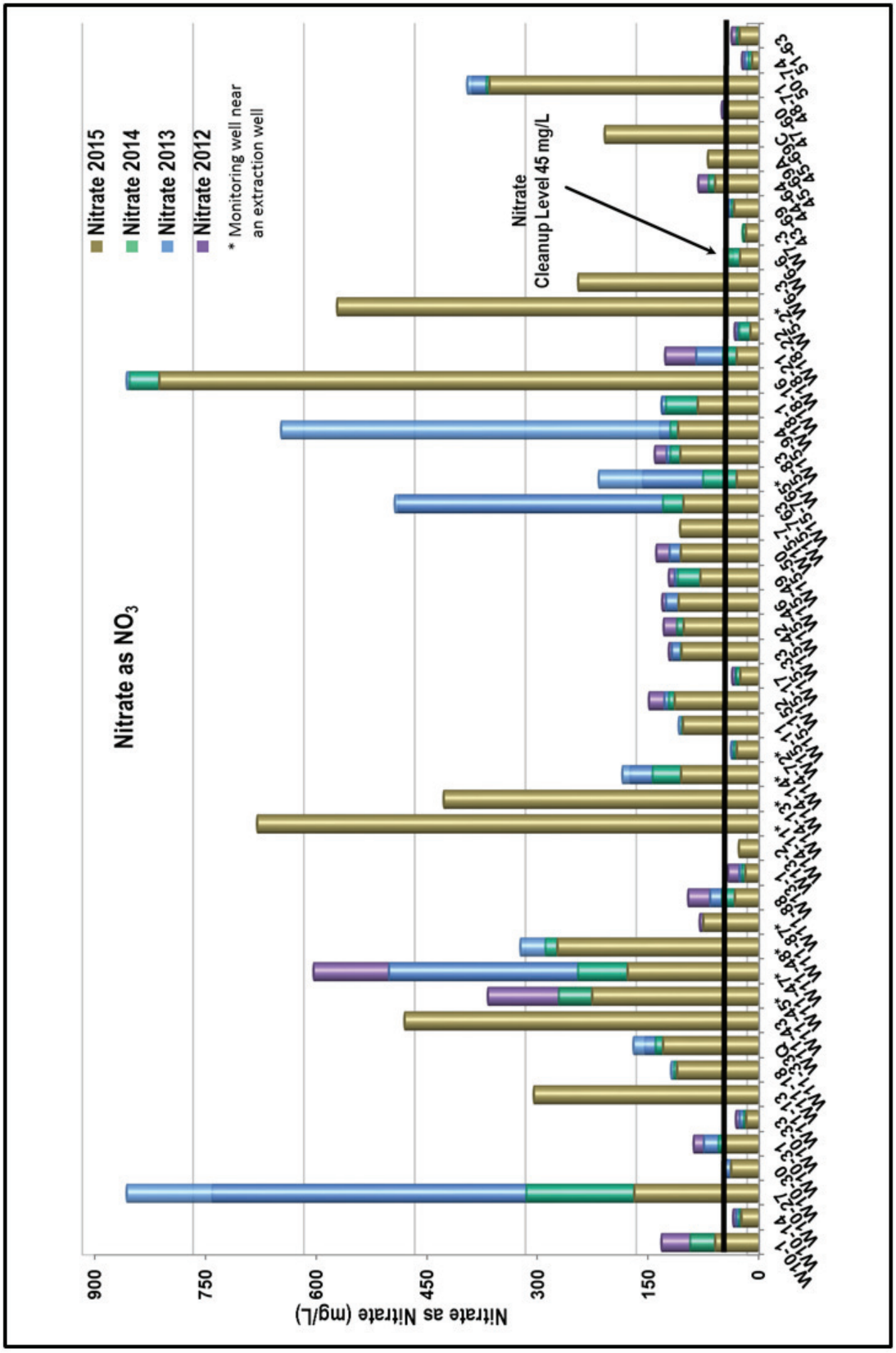


Figure 3-27. Contaminant Plume Map for Nitrate, 2015



Note: Wells with increasing concentrations in 2015 are shown as solid brown bars in the figure.

Figure 3-28. Comparison of Nitrate Concentrations in 200-ZP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015

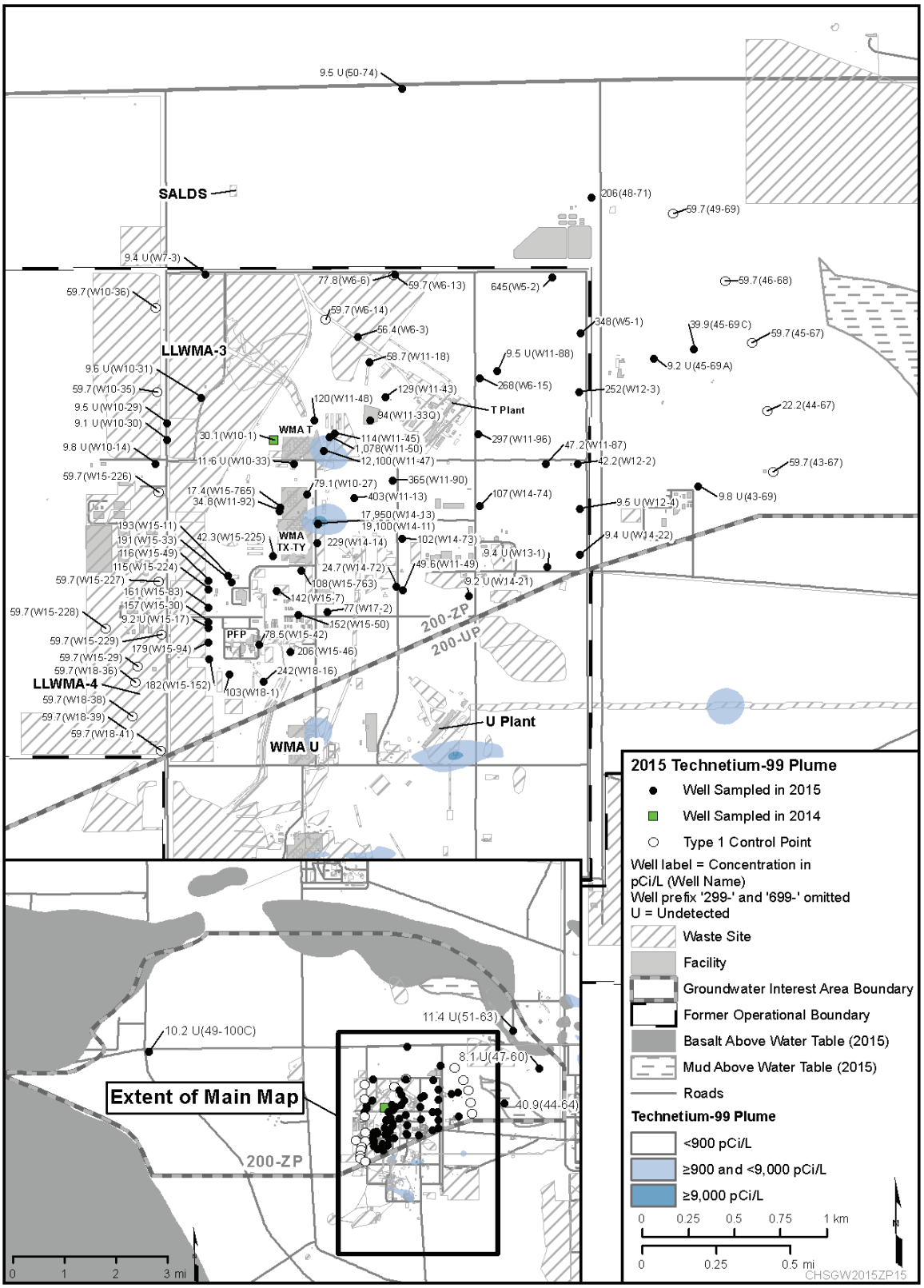
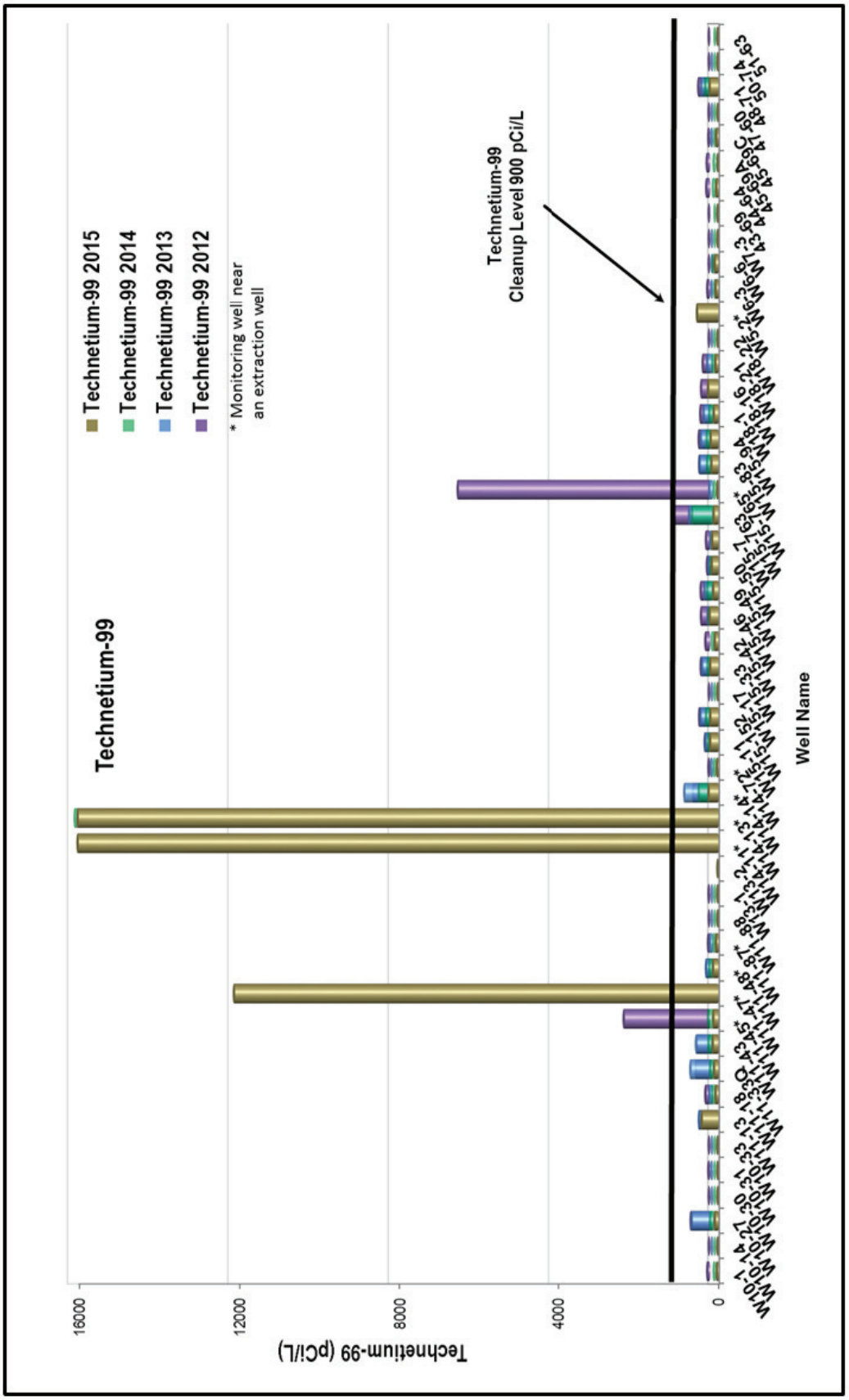


Figure 3-29. Contaminant Plume Map for Technetium-99, 2015



Note: Wells with increasing concentrations in 2015 are shown as solid brown bars in the figure.

Figure 3-30. Comparison of Technetium-99 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015

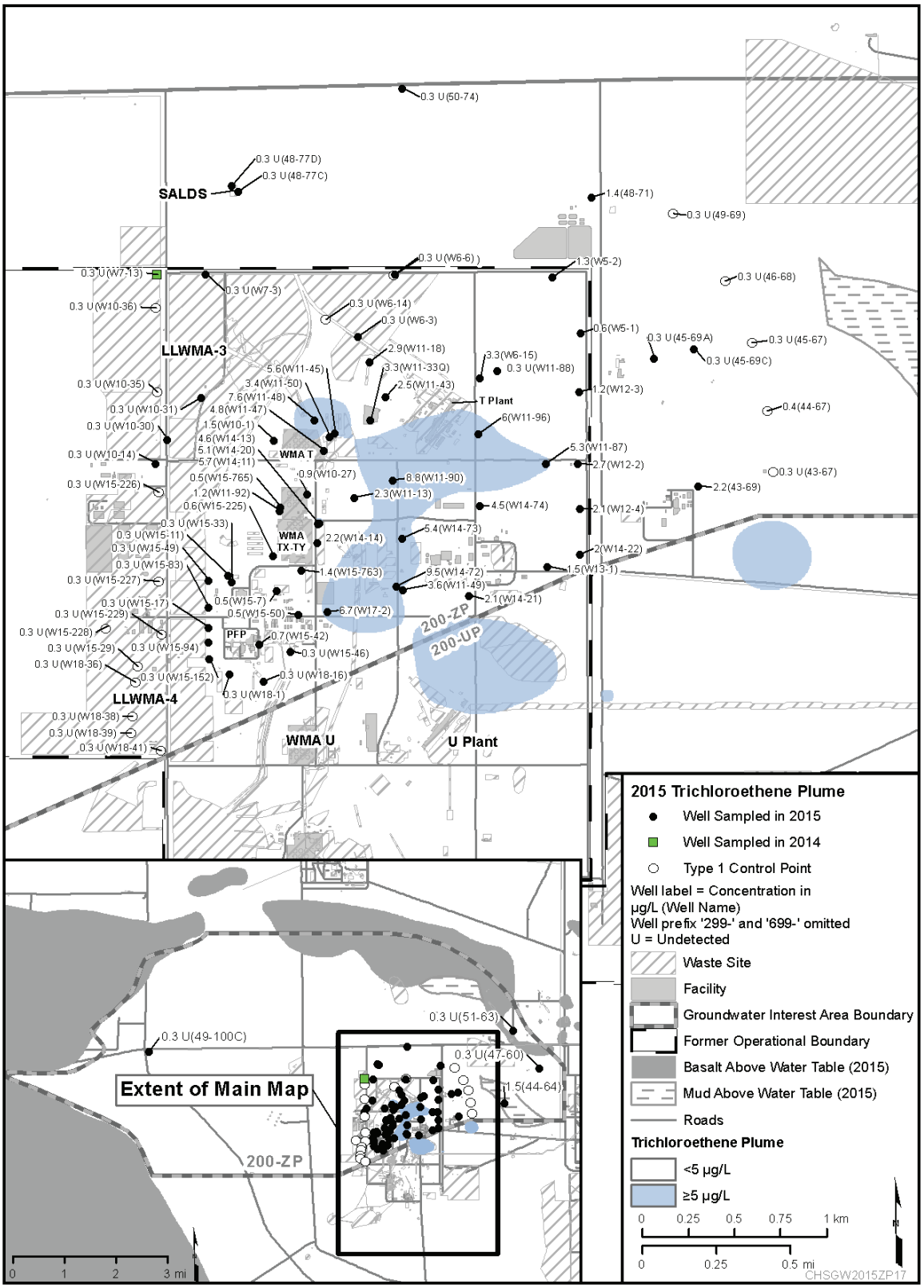


Figure 3-31. Contaminant Plume Map for Trichloroethene, 2015

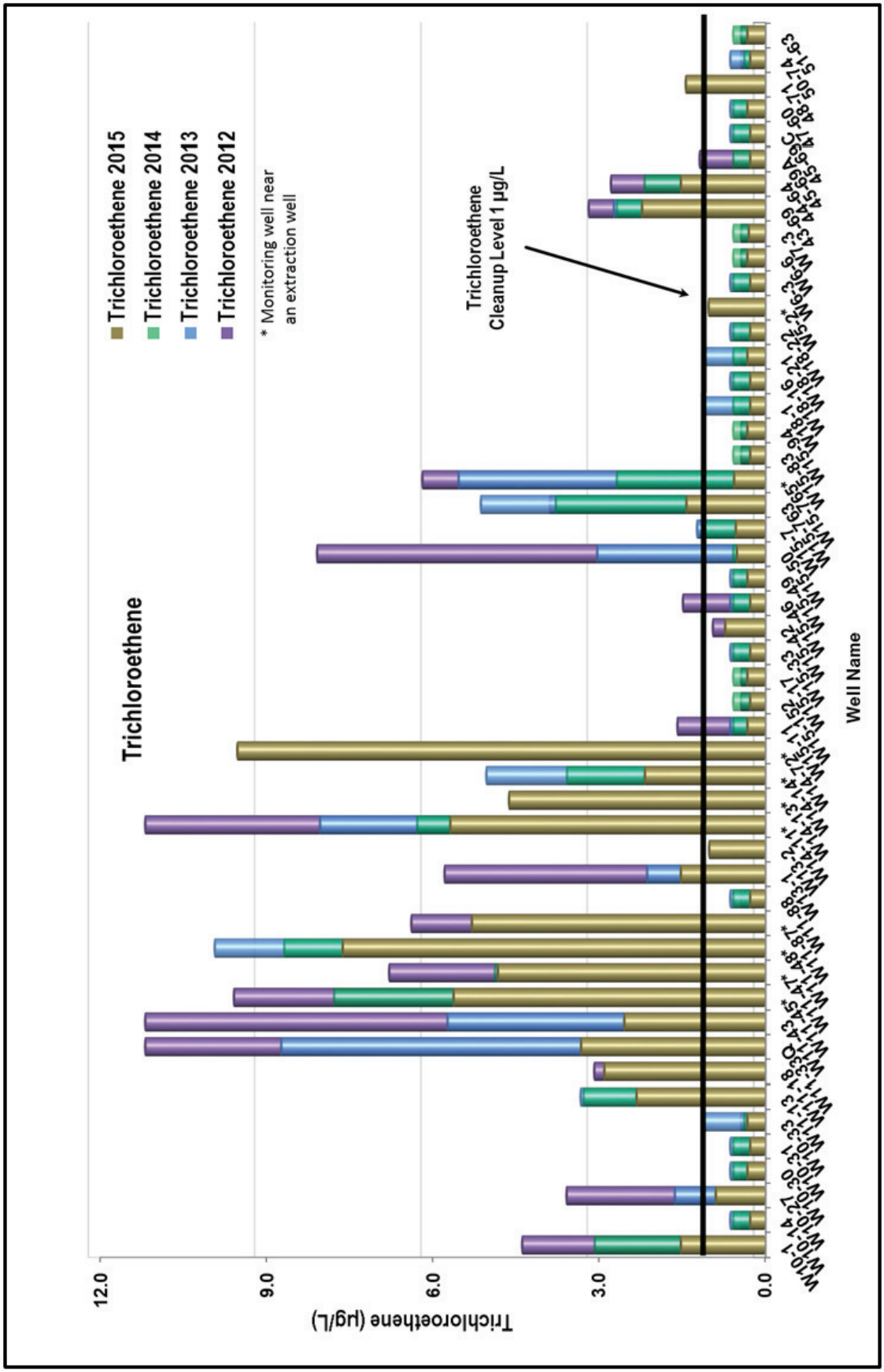
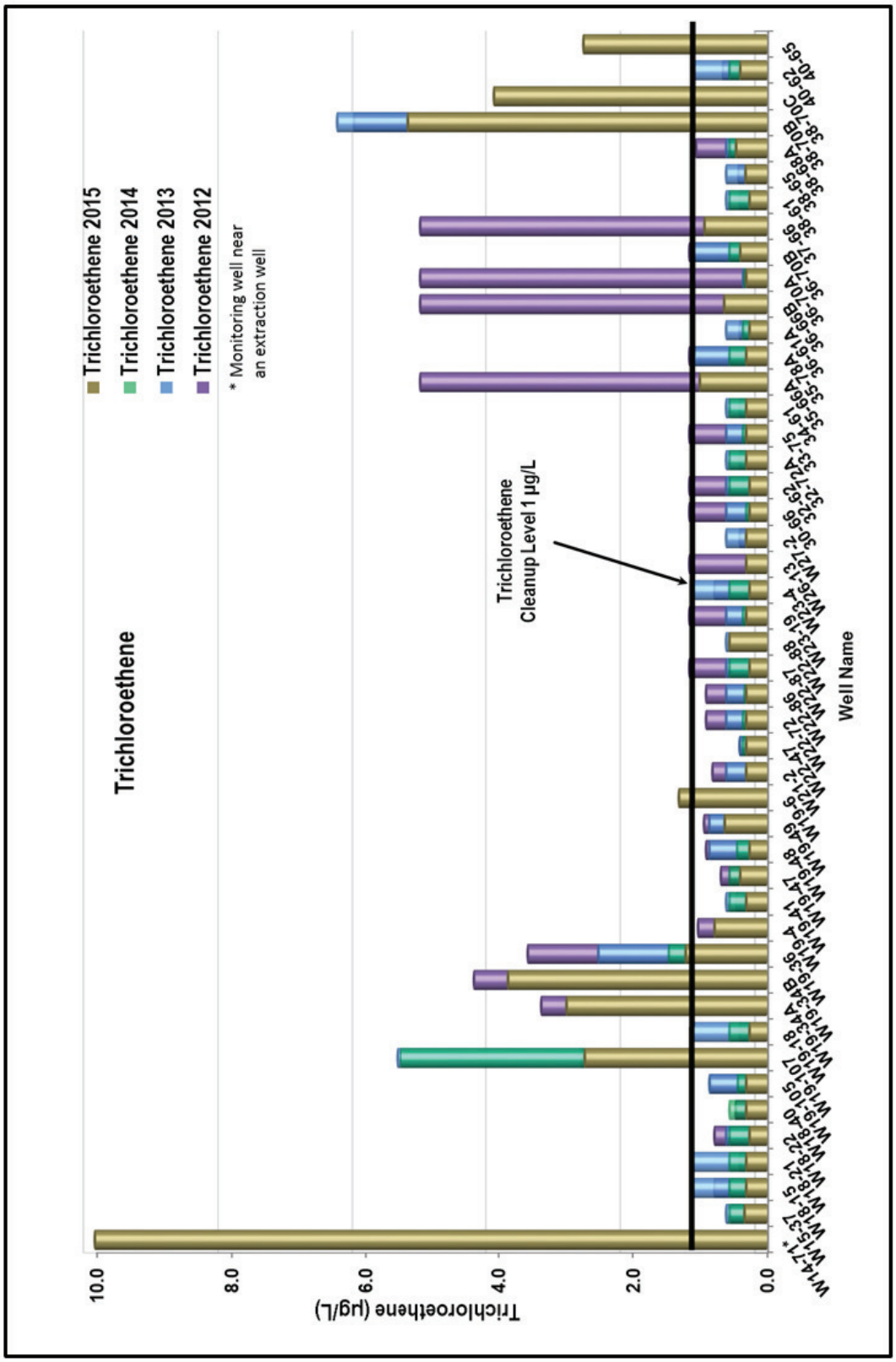


Figure 3-32. Comparison of Trichloroethene Concentrations in 200-ZP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015



Note: Wells with increasing concentrations in 2015 are shown as solid brown bars in the figure.

Figure 3-33. Comparison of Trichloroethene Concentrations in 200-UP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015

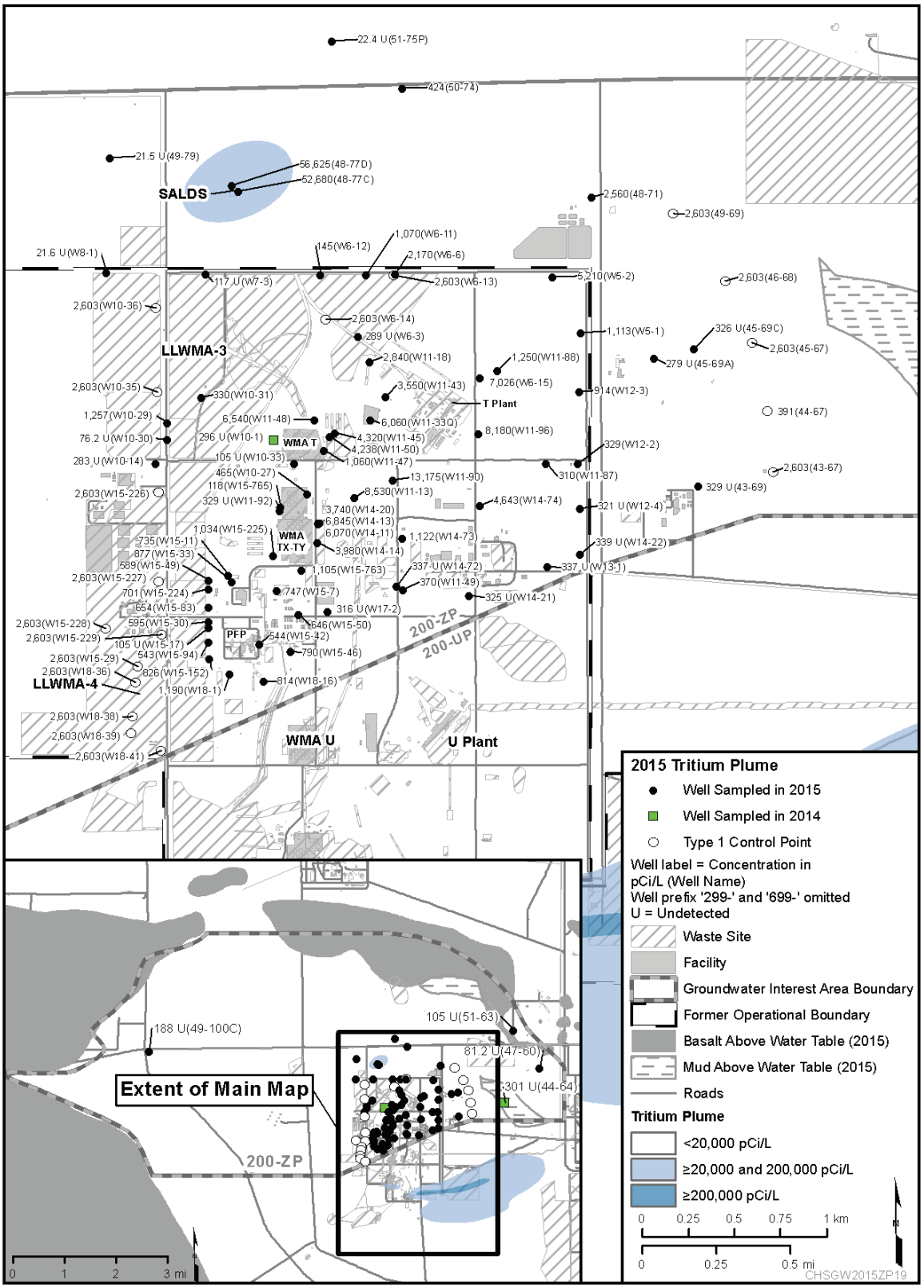


Figure 3-34. Contaminant Plume Map for Tritium, 2015

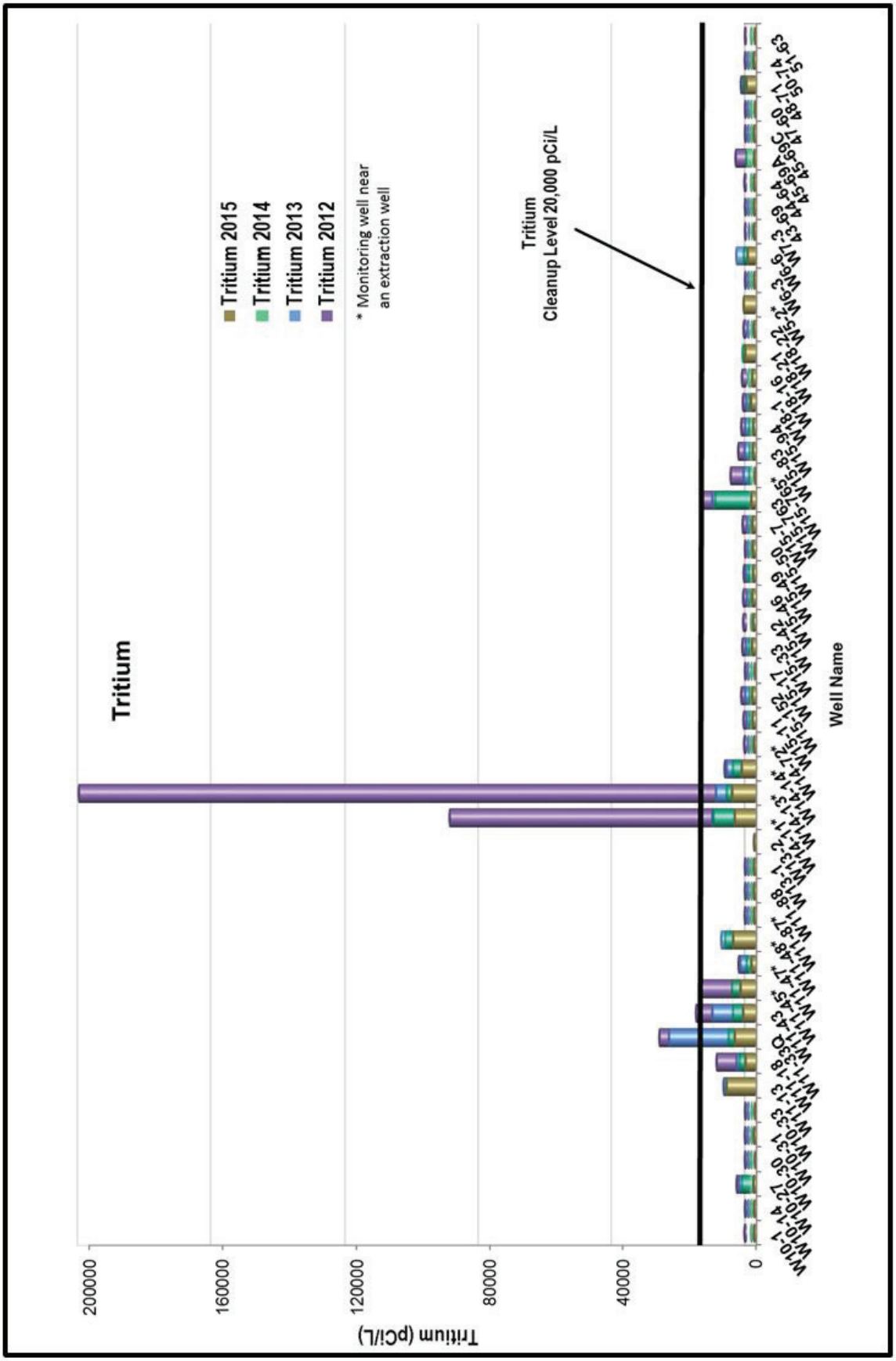


Figure 3-35. Comparison of Tritium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012, 2013, 2014, and 2015

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 data quality objective process for the 200 West P&T (DOE/RL-2009-115). The PMP describes key questions that the data collection must address, along with alternative actions that may result:

- **DS #1:** Determine if any new releases of COCs could impact the effectiveness of the remedy and necessitate changes to the remedial action and/or PMP; otherwise, continue with the current remedial action and PMP.
- **DS #2:** Determine if potentially toxic and/or mobile transformation products are being generated at concentrations large enough to justify their inclusion in the list of COCs with associated cleanup levels; otherwise, continue with the current list of COCs and associated cleanup levels.
- **DS #3:** Determine if changes are occurring in environmental conditions that may reduce the efficacy of the P&T system, natural attenuation processes, and the flow-path control actions, thereby necessitating changes to the remedial action and/or PMP; otherwise, continue with the current remedial action and PMP.
- **DS #4:** Determine if the P&T system will remove at least 95 percent of the mass of COCs in 25 years or less, and thereby achieve remedy goals for the P&T phase of the remedy; otherwise, evaluate modifications to the P&T system that could achieve the stated goal for the P&T phase of the remedy.
- **DS #5:** Determine if contamination is expanding downgradient, laterally, or vertically after the P&T component has been turned off, thereby necessitating an evaluation of the predicted success of the remedial action; otherwise, continue with the current remedial action and PMP.
- **DS #6:** Determine if the current remedy design is predicted to achieve cleanup levels for all COCs within 125 years, and thereby achieve the overall remedial goal; otherwise, evaluate modifications to the remedial action that could achieve the stated goal for the overall remedy.
- **DS #7:** Determine if remediation has been successfully completed, and a recommendation can be made for no further action; otherwise, continue with the current remedial action and PMP, or determine if a technical impracticability waiver should be invoked.
- **DS #8:** Determine if certain areas of the contaminant plumes are not responding to P&T remediation as expected, and therefore require the evaluation of other technologies for a more focused or "hot spot" remedy; otherwise, no new action is required.
- **DS #9:** Once 95 percent of the mass of COCs has been removed, determine if there is a rebound in COC concentrations, which would require the P&T system to be turned back on; otherwise, leave the P&T system off, and begin to monitor the natural attenuation.

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 3-36).

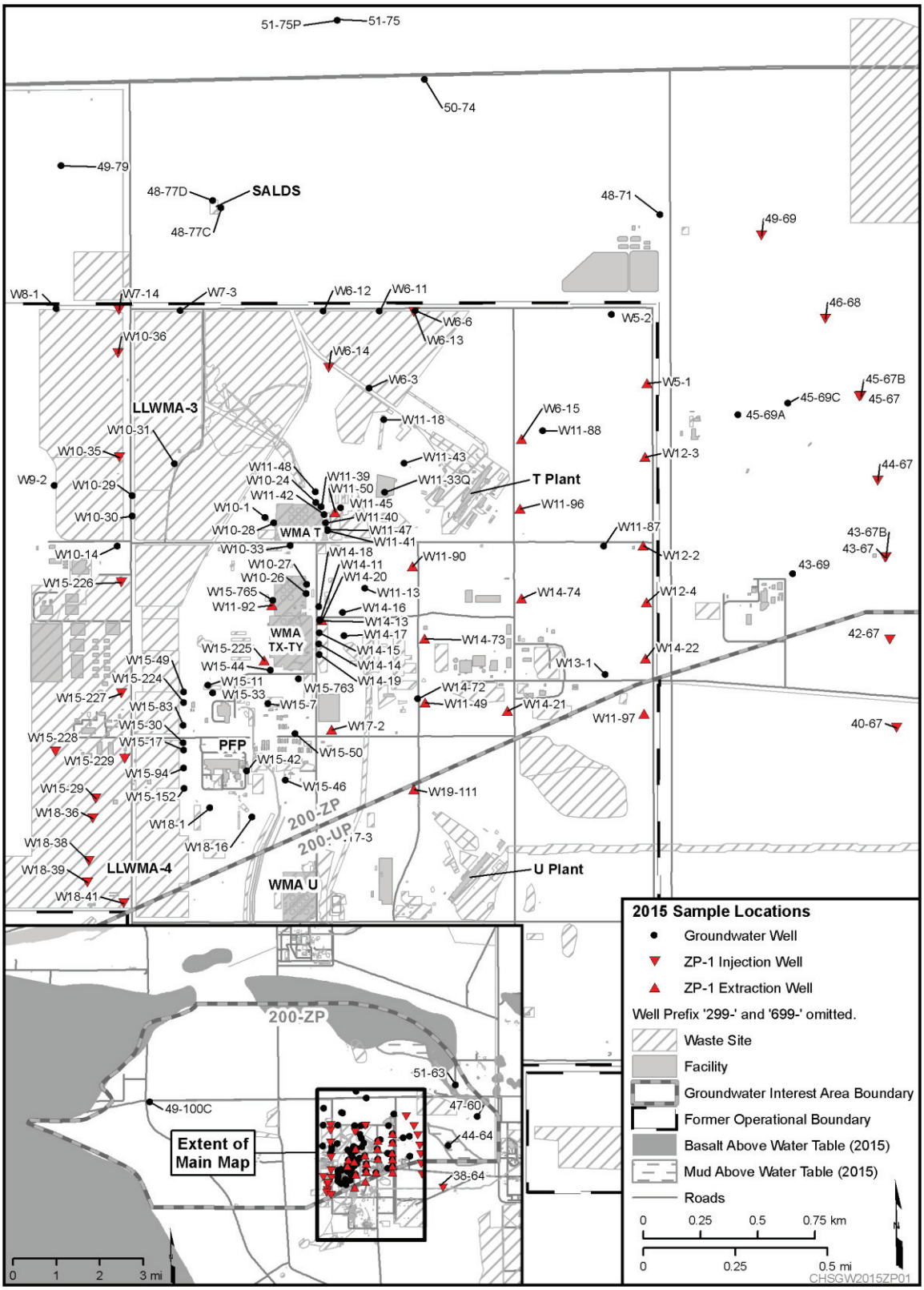


Figure 3-36. 200-ZP-1 OU Groundwater Well Network, 2015

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 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. 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; however, annual sampling from the contaminant specific well list will provide data for assessing DSs #1, #2, and #5. This includes determining 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 U.S. Environmental Protection Agency (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 CP Model to assist with remedy optimization.

3.3.2 Contaminant Monitoring Data

The 2015 contaminant monitoring results for the 200 West Area are summarized below by COC. The 2015 average concentrations are presented in Table 3-6. 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 2015, 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-16-0061, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2015 Hanford Site Groundwater Monitoring Report*).

In preparation for this P&T report, three-dimensional depictions of the extent of contamination were also prepared for use in groundwater contaminant fate and transport calculations. These calculations are described in Section 3.3.3.

3.3.2.1 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, *Superfund Record of Decision: Hanford 200-Area (USDOE) OU 200-ZP-1, Benton County, WA*) to 3.4 µg/L and targeted the entire thickness of the plume. Figure 3-20 illustrates the carbon tetrachloride distribution at concentrations greater than 3.4 µg/L based on maximum sample concentrations during 2015 (see Section 3.3.4).

Table 3-6. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2015

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 2015?
299-W10-1	500	68.4	2.3	<0.21	57.5	28	1.50	<301	1.13	Yes
299-W10-14	<0.1	15.0	2.4	<0.19	22.0	<10	<0.25	<283	0.94	Yes
299-W10-27	140	12.7	11.5	<0.34	167.0	79	0.87	465	1.54	Yes
299-W10-30	7	2.6	3.4	<0.77	35.9	<10	<0.30	<76	0.83	Yes
299-W10-31	20	2.5	3.1	<0.45	44.3	<10	<0.25	<309	1.30	Yes
299-W10-33	<0.3	2.1	<1.5	<0.85	15.4	<12	<0.30	<105	1.34	Yes
299-W11-13	260	278.0	26.9	<0.33	303.0	403	2.30	8,530	1.12	Yes
299-W11-18	297	30.3	27.9	<0.44	109.0	59	2.88	2,840	1.28	Yes
299-W11-33Q	360	35.9	28.0	<0.63	128.0	94	3.30	6,060	1.15	Yes
299-W11-43	231	206.0	198.0	<0.79	478.0	129	2.52	3,550	2.50	Yes
299-W11-45	890	72.1	69.4	<0.54	224.0	114	5.60	4,320	0.72	Yes
299-W11-47	1,220	33.5	37.5	<0.21	176.0	12,100	4.80	1,060	0.81	Yes
299-W11-48	1,000	82.9	86.8	<0.37	271.0	120	7.60	6,540	1.18	Yes
299-W11-87	1,980	7.2	5.8	<0.56	73.5	47	5.27	310	1.18	Yes
299-W11-88	<0.1	1.8	<1.5	<0.25	30.8	<9	<0.3	2,160	1.02	Yes
299-W13-1	370	72.7	11.7	<0.19	16.5	<9	1.5	<337	0.90	Yes
299-W13-2	62.7	3.37	1.5	<0.03	253.9	<1.6	0.99	104.1	1.28	Yes
299-W14-11	1,510	72.3	80.4	<1.05	677.5	19,100	5.66	6,070	2.25	Yes
299-W14-13	880	30.8	12.7	0.65	425.0	17,950	4.60	6,845	2.15	Yes

Table 3-6. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2015

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 2015?
299-W14-14	529	18.0	7.4	<0.70	103.8	229	2.15	3,980	1.10	Yes
299-W14-71	612	—	—	—	—	—	10.40	—	—	Yes
299-W14-72	1,200	7.3	2.1	<0.29	28.2	25	9.50	<337	0.73	Yes
299-W15-11	103	8.4	8.1	<0.51	101.0	193	0.30	735	0.86	Yes
299-W15-152	4.9	10.2	8.5	<0.38	112.3	182	<0.25	826	2.09	Yes
299-W15-17	1.4	15.4	1.6	<0.42	23.5	<9	<0.30	<105	0.81	Yes
299-W15-33	82	9.4	7.2	<0.29	103.0	191	<0.25	877	0.91	Yes
299-W15-37	168	—	—	—	—	—	0.35	—	—	Yes
299-W15-42	88	11.2	10.0	<0.16	100.0	79	0.70	544	1.61	Yes
299-W15-46	70	8.0	6.5	<0.19	107.0	206	<0.25	790	0.69	Yes
299-W15-49	74	6.2	9.7	<0.69	77.5	116	0.30	589	0.83	Yes
299-W15-50	210	7.4	7.9	<0.15	104.0	152	0.49	646	0.80	Yes
299-W15-7	376	6.8	<1.5	<0.85	105.0	142	0.51	747	1.06	Yes
299-W15-763	490	37.9	4.6	<0.27	100.5	108	1.40	1,105	1.17	Yes
299-W15-765	182	19.2	4.0	0.88	28.3	17	0.54	118	1.16	Yes
299-W15-83	21	9.8	5.8	<0.42	104.6	161	<0.25	654	0.98	Yes
299-W15-94	13	8.4	8.3	<0.85	107.7	179	<0.30	543	0.94	Yes
299-W18-1	6	8.0	6.6	<0.57	81.0	103	<0.25	1,190	2.74	Yes
299-W18-15	18	—	—	—	—	—	<0.30	—	—	Yes

Table 3-6. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2015

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 2015?
299-W18-16	58	11.2	12.3	<0.25	810.0	242	<0.25	814	2.85	Yes
299-W18-21	<0.3	—	—	—	—	—	<0.3	—	—	Yes
299-W18-22	1.1	—	—	—	—	—	<0.25	—	—	Yes
299-W18-40	116	—	—	—	—	—	<0.30	—	—	Yes
299-W19-105	31	—	—	—	—	—	<0.30	—	—	Yes
299-W19-107	82	—	—	—	—	—	2.70	—	—	Yes
299-W19-18	<0.1	—	—	—	—	—	<0.25	—	—	Yes
299-W19-34A	92	—	—	—	—	—	2.97	—	—	Yes
299-W19-34B	135	—	—	—	—	—	3.84	—	—	Yes
299-W19-36	10	—	—	—	—	—	1.20	—	—	Yes
299-W19-4	48	—	—	—	—	—	0.77	—	—	Yes
299-W19-41	99	—	—	—	—	—	<0.30	—	—	Yes
299-W19-47	165	—	—	—	—	—	0.39	—	—	Yes
299-W19-48	42	—	—	—	—	—	<0.25	—	—	Yes
299-W19-49	169	—	—	—	—	—	0.62	—	—	Yes
299-W19-6	45	—	—	—	—	—	1.30	—	—	Yes
299-W21-2	32	—	—	—	—	—	<0.30	—	—	Yes
299-W22-47	107	—	—	—	—	—	<0.30	—	—	Yes

Table 3-6. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2015

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 2015?
299-W22-72	41	—	—	—	—	—	<0.30	—	—	Yes
299-W22-86	18	—	—	—	—	—	<0.30	—	—	Yes
299-W22-87	18	—	—	—	—	—	<0.25	—	—	Yes
299-W22-88	9	—	—	—	—	—	0.55	—	—	Yes
299-W23-19	90	—	—	—	—	—	<0.30	—	—	Yes
299-W23-4	80	—	—	—	—	—	<0.25	—	—	Yes
299-W26-13	0.7	—	—	—	—	—	<0.25	—	—	Yes
299-W27-2	6	—	—	—	—	—	<0.3	—	—	Yes
299-W5-2	231	62	21.7	0.9	569.3	420.1	1.0	3370	1.34	Yes
299-W6-3	<0.1	20.2	9.2	<0.16	243.0	56	<0.25	<289	0.95	Yes
299-W6-6	<0.3	19.5	12.2	<0.84	23.9	78	<0.30	2,170	1.10	Yes
299-W7-3	0.4	14.9	3.0	<0.35	15.8	<9	<0.30	<117	0.80	Yes
699-30-66	0.5	—	—	—	—	—	<0.25	—	—	Yes
699-32-62	<0.1	—	—	—	—	—	<0.25	—	—	Yes
699-32-72A	0.92	—	—	—	—	—	<0.30	—	—	Yes
699-33-75	5.9	—	—	—	—	—	<0.30	—	—	Yes
699-34-61	0.8	—	—	—	—	—	<0.30	—	—	Yes
699-35-66A	0.9	—	—	—	—	—	0.99	—	—	Yes
699-35-78A	20.9	—	—	—	—	—	<0.30	—	—	Yes

Table 3-6. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2015

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 2015?
699-36-61A	0.4	—	—	—	—	—	<0.25	—	—	Yes
699-36-66B	2.5	—	—	—	—	—	0.63	—	—	Yes
699-36-70A	2.7	—	—	—	—	—	<0.30	—	—	Yes
699-36-70B	13.9	—	—	—	—	—	0.39	—	—	Yes
699-37-66	1.7	—	—	—	—	—	0.92	—	—	Yes
699-38-61	<0.3	—	—	—	—	—	<0.25	—	—	Yes
699-38-65	1.0	—	—	—	—	—	0.31	—	—	Yes
699-38-68A	3.4	—	—	—	—	—	0.45	—	—	Yes
699-38-70B	318	—	—	—	—	—	5.33	—	—	Yes
699-38-70C	26.5	—	—	—	—	—	4.05	—	—	Yes
699-40-62	0.5	—	—	—	—	—	0.39	—	—	Yes
699-40-65	4.8	—	—	—	—	—	2.72	—	—	Yes
699-43-69	220.0	86.8	31.5	<0.59	31.8	<10	2.20	<329	1.43	Yes
699-44-64	9.4	12.8	7.3	<0.23	57.5	41	1.5	<302	1.71	Yes
699-45-69A	13.0	33.9	8.2	<0.54	67.3	<9	<0.25	<279	1.54	Yes
699-45-69C	36.0	38.9	29.5	<0.53	207.0	40	<0.25	<326	1.27	Yes
699-47-60	<0.30	221.0	5.6	<1.16	41.3	<8	<0.30	<81	2.42	Yes
699-48-71	174.0	146.0	89.0	0.50	336.0	201	1.41	2,910	1.29	Yes
699-50-74	<0.1	7.3	4.5	<0.32	7.5	<10	<0.25	424	1.40	Yes

Table 3-6. Average Concentration of COCs for the 200-ZP-1 OU Monitoring Wells in 2015

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 2015?
699-51-63	<0.3	2.5	1.6	<0.35	24.5	<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

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. During 2015, 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 3-19). 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 2015, none of the monitoring wells exceeded 2,000 µg/L of carbon tetrachloride. Well 299-W11-87 (a CERCLA monitoring well) had a maximum concentration of 1,980 µg/L. Wells 299-W14-11, 299-W11-90, and 299-W11-96 had the next highest concentrations at 1,510 µg/L; 1,500 µg/L; and 1,400 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 1,300 µg/L and 1,220 µg/L, respectively. Of the 97 wells sampled in 2015 in the 200 West Area, 29 were below the cleanup level (3.4 µg/L), and 92 wells were below 1,000 µg/L.

Figure 3-21 illustrates a comparison of the 2012, 2013, 2014, and 2015 carbon tetrachloride concentrations in the 200-ZP-1 OU monitoring wells; Figure 3-22 illustrates the comparison for the 200-UP-1 OU monitoring wells. After only 3.3 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. During 2015, carbon tetrachloride concentrations declined in 44 of 97 monitoring wells sampled, 23 wells had increasing concentrations, and 30 wells had concentrations about the same as the 2012 concentrations (less than 20 percent difference between 2012 and 2015 concentrations). Most of the wells with increasing concentrations are located near extraction wells that are drawing contamination in from the surrounding area; as such, increases in concentration are not unexpected.

Soil vapor extraction (SVE) was being used to remove carbon tetrachloride from the 200-PW-1 OU vadose zone overlying the 200-ZP-1 OU groundwater to mitigate migration of contamination to groundwater. SVE was initially implemented as an expedited response action in 1992 and was selected as the final remedy in EPA et al., 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*. Between 1991 (pilot testing) and 2012, SVE removed 80,107 kg of carbon tetrachloride from the vadose zone (SGW-54566, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride site, Calendar Year 2012*). During 2013, 2014, and 2015, SVE systems were not operated while annual rebound studies of carbon tetrachloride concentrations were conducted. Carbon tetrachloride concentrations in wells did not rebound above the cleanup level. The SVE 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 has met the RAOs in the ROD and SVE activities can be ended. Preparation of a response action report was initiated in 2015 to close out the SVE portion of the 200-PW-1 OU remedy in the ROD.

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. Figure 3-23 shows the extent of the chromium plume throughout the unconfined aquifer. 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. In Hanford Site groundwater, both have similar concentrations within any given well because the mobile form of chromium is hexavalent. In this section, sample results for total chromium and hexavalent chromium will

be referred to together simply as chromium, and the effective cleanup level is 48 µg/L because it is more restrictive.

In 2015, the 200-ZP-1 OU maximum chromium concentration of 278 µg/L was downgradient from WMA T in 299-W11-13. This was an increase from 51 µg/L measured in this well in 2012. Concentrations exceeding the cleanup standard were found at 6 of the 50 monitoring wells in the 200-ZP-1 OU. The chromium plumes are migrating eastward in the OU and are within the capture zones of the 200 West P&T extraction wells (Figure 3-23). A comparison of chromium sampling results in 2012, 2013, 2014, and 2015 indicates that concentrations are declining (Figure 3-24). During 2015, chromium concentration declined approximately 53 percent in one of the six monitoring wells with concentrations exceeding the cleanup level (299-W11-45); two wells had an increase in concentration (299-14-11 and 699-48-71), and two wells had concentrations similar to those observed in 2012. Well 299-W14-11 is located next to extraction well 299-14-20 drawing in contaminated groundwater. The second 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 one well in the northeast corner of 200-ZP-1. Sources of iodine-129 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 3-25 shows the extent of the iodine-129 plume throughout the unconfined aquifer. In 2015, the maximum reported concentration of 1.38 pCi/L was at 299-W5-2 (Table 3-7), a new monitoring well drilled in 2015. Samples collected during drilling revealed that iodine-129 exceeded the cleanup level. Concentrations also exceeded the 1 pCi/L cleanup level in 2013 during drilling of 299-W6-15 (with 1.22 pCi/L), located east of T Plant. 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 3-25). During operations in 2015, 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, 2013, 2014, and 2015 (Figure 3-26). Iodine-129 concentrations in 2015 are below the cleanup level of 1 pCi/L in 49 of 50 monitoring wells.

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. The size and concentration of contours in 2015 are slightly smaller than those reported in 2014 (Figure 3-27). The size of the 2015 nitrate plume (concentrations above 45 mg/L) in 200-ZP-1 was about 18 percent smaller than the 2014 nitrate plume. Sources of nitrate include liquid waste disposal from PFP processes to the cribs near WMA T and the 216-Z Cribs and Trenches. Two discrete, high-concentration plumes are discernible (Figure 3-27): a plume located beneath WMA T and WMA TX-TY, and a plume observed at 299-W18-16 (near the 216-Z Cribs and Trenches). 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 2015 was 810 mg/L at 299-W18-16 (Table 3-7), which is a CERCLA 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. Figure 3-28 illustrates changes in the 2012, 2013, 2014, and 2015 nitrate concentrations in 200-ZP-1 OU monitoring wells. During 2015, 13 monitoring wells had decreasing concentrations, 10 had increasing concentrations, and 27 had concentrations about the same (less than a 20 percent difference in concentration) as reported in 2012. Of the 10 wells with increasing concentrations, 4 of the wells are located near extraction wells drawing in contaminated groundwater. The remaining six wells had increasing concentrations due to plume migration.

Table 3-7. 200-ZP-1 OU at a Glance

T Plant Operations: 1944 to 1956 (Plutonium Separation)
PFP Operations: 1949 to 1989

2015 Groundwater Monitoring

Contaminant	Final Cleanup Level	Maximum Concentration	Plume Area[a] (km^2)
Carbon Tetrachloride	3.4 µg/L	1,980 µg/L (299-W11-87)	10.99[b]
Chromium (Trivalent and Hexavalent)	100/48 µg/L[c,d]	278/198 µg/L (299-W11-13)	0.64
Iodine-129	1 pCi/L	1.38 pCi/L (299-W5-2)	0.09
Nitrate[e]	45 mg/L	810 mg/L (299-W18-16)	7.17
Technetium-99	900 pCi/L	20,500 pCi/L (299-W14-13)	0.06
Trichloroethene	1 µg/L	12 µg/L (299-W11-90)	2.88
Tritium	20,000 pCi/L	13,500 pCi/L (299-W11-90)	0.20

Remediation

Note: 200-ZP-1 OU P&T (interim action 1996 to 2012) removed:

- 13,718 kg carbon tetrachloride

WMA T P&T (interim action 2007 to 2012) removed:

- 193 kg carbon tetrachloride
- 14.5 kg chromium
- 84,693 kg nitrate
- 81.7 g technetium-99
- 732 g trichloroethene

200-PW-1 OU soil vapor extraction (expedited response action):

- 1991 to 2012, removed 80,107 kg carbon tetrachloride
- 2013 and 2014, soil vapor extraction systems offline for rebound study
- 200-PW-1 final action ROD (EPA et al., 2011)
- 200-ZP-1 final action ROD (EPA et al., 2008)

200 West P&T (final action July 2012 to December 2015) removed:

- 9,264 kg carbon tetrachloride
- 250 kg chromium (total and hexavalent)
- 242 pCi iodine-129
- 844,113 kg nitrate as nitrate; 190,601 kg nitrate as nitrogen
- 284 g technetium-99
- 36.7 kg trichloroethene

Table 3-7. 200-ZP-1 OU at a Glance

T Plant Operations: 1944 to 1956 (Plutonium Separation) **PFP Operations:** 1949 to 1989			
2015 Groundwater Monitoring			
Contaminant	**Final Cleanup Level**	**Maximum Concentration**	**Plume Area[a] (km^2)**

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

OU = operable unit
P&T = pump and treat
PFP = Plutonium Finishing Plant
WMA = waste management area

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 3-29 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 20,500 pCi/L in 299-W14-13 (a CERCLA and *Resource Conservation and Recovery Act of 1976* monitoring well), which is 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 2015 (Table 3-6; Figure 3-30). With the exception of monitoring wells located near extraction wells, technetium-99 concentrations declined in all other monitoring wells in the 200-ZP-1 OU in 2015.

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 3-31). TCE contamination is found from the water table to the bottom of the aquifer. The maximum TCE concentration reported during 2015 was 12 µg/L in 299-W11-90, which is slightly more than the 2012 concentration of 10 µg/L. The increase in concentration is because the well is an extraction well, which is drawing in contaminated water from surrounding areas. The highest TCE concentrations in monitoring wells were found in 299-W14-71 and 299-W14-72 at 10.4 and 9.5 µg/L, respectively. TCE concentrations decreased in most of the 200-ZP-1 and 200-UP-1 OU monitoring wells in 2012, 2013, 2014, and 2015 (Figures 3-32 and 3-33). For example, 299-W11-33Q decreased from 11 µg/L in 2012 to 3.3 µg/L in 2015, 299-W11-43 decreased from 11 to 2.5 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 27 of the 97 monitoring wells in the 200 West Area in 2015.

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) (Figure 3-34). 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 2015 in the 200-ZP-1 OU was 13,500 pCi/L at 299-W11-90 (an extraction well located downgradient of WMA T and WMA TX-TY) (Figure 3-35). Tritium located near WMA T and WMA TX-TY was contained by the 200 West P&T extraction wells.

3.3.2.2 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 abiotic degradation, dispersion, sorption, and natural 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. 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 3-8 presents the average data for the natural attenuation daughter products and the field parameters in the contaminant monitoring well network during 2015. During 2012 and 2013, data were collected to provide baseline concentrations to track natural attenuation and transformation products in monitoring wells. These data are being compared to data from 2015 and will be compared to future data to determine actual rates of attenuation.

3.3.3 Summary of Contaminant Monitoring Data

Concentrations of carbon tetrachloride are declining due to remediation activities (Figure 3-21). 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 100 percent, from 530,000 m^2 (5,704,873 ft^2) in 1996 to zero in 2014. The highest carbon tetrachloride concentration in 2015 (1,980 µg/L) was found in 299-W11-87 (a monitoring well). All 200-ZP-1 and 200-UP-1 OU wells had carbon tetrachloride concentrations less than 2,000 µg/L. The 200 West P&T will 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 2015 was 810 mg/L at 299-W18-16 (Table 3-7). This was a 50 percent 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. Nitrate concentrations in 200-ZP-1 OU monitoring wells are declining in most wells as a result of remedial efforts at the 200 West P&T.

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-W14-11, technetium-99 concentrations increased from 3,500 pCi/L in 2012 to 19,100 pCi/L in 2015; in 299-W14-13, technetium-99 concentrations increased from 5,900 to 20,500 pCi/L. 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. The increases show that contamination is being drawn toward the extraction well and is being removed.

Table 3-8. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in Contaminant Monitoring Well Network in 2015

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 (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W10-1	19,000	5.6	<0.20	<0.23	<0.68	9,220	<0.04	298.6	7.95	438	18.1	4.41	<0.20
299-W10-14	10,600	<0.1	<0.08	<0.09	<0.27	3,470	<0.04	149.1	8.09	356	19.6	0.67	<0.08
299-W10-27	25,033	12.0	<0.08	<0.09	<0.27	10,428	<0.04	287.3	8.17	699	20.0	387.48	<0.08
299-W10-30	21,300	0.5	<0.30	<1.00**	<1.60	10,171	<0.04	220.9	7.97	411	19.5	1.70	<0.30
299-W10-31	23,800	0.7	<0.08	<0.09	<0.27	9,720	<0.04	281.9	7.98	470	18.7	1.87	<0.08
299-W10-33	7,180	<0.3	<0.30	<1.00**	<1.60	360	<0.04	66.2	7.89	327	19.8	0.39	<0.30
299-W11-13	57,200	8.4	<0.08	<0.09	<0.27	11,550	<0.04	339.9	7.89	965	17.8	20.50	<0.08
299-W11-18	9,930	4.2	<0.30	<1.00**	<1.60	7,290	<0.04	356.6	8.05	307	18.0	278.00	<0.30
299-W11-33Q	16,000	4.9	<0.40	<0.45	<1.40	8,650	<0.04	259.1	7.87	545	19.3	47.70	<0.40
299-W11-43	13,100	3.6	<0.30	<1.0*	<1.60	9,520	<0.04	417.9	7.62	1215	19.5	0.44	<0.30
299-W11-45	16,750	8.4	<0.20	<0.23	<0.68	8,740	<0.04	265.2	7.98	761	18.7	2.49	<0.20
299-W11-47	18,000	10.3	<0.30	<1.00**	<1.60	9,295	<0.04	293.2	7.92	722	19.5	3.36	<0.30
299-W11-48	21,700	8.9	<0.20	<0.09	<0.68	11,010	<0.04	166.8	7.86	858	18.2	0.09	<0.20
299-W11-87	53,900	8.3	<0.30	<1.0*	<1.60	11,120	<0.04	374.8	7.75	615	19.7	0.53	<0.30
299-W11-88	7,550	0.3	<0.08	<0.09	<0.27	1,710	<0.04	191.0	7.99	375	19.8	2.07	<0.08
299-W13-1	25,000	2.9	<0.08	<0.09	<0.27	10,430	<0.04	398.1	7.83	493	18.5	3.38	<0.08
299-W13-2	***	3.82	<0.24	***	1.29	7,618	***	65.3	7.48	1220	20.8	190.3	<0.24
299-W14-11	35,100	10.2	<0.30	<1.00**	<1.60	8,005	<0.04	218.3	7.46	1539	21.6	2.22	<0.30

Table 3-8. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in Contaminant Monitoring Well Network in 2015

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 (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W14-13	48,900	7.5	<0.40	<0.45	<1.40	8,353	<0.04	321.9	7.77	1285	18.1	6.96	<0.40
299-W14-14	27,250	5.6	<0.30	<1.00**	2.14	8,620	<0.04	245.2	8.10	584	20.9	3.14	<0.30
299-W14-71	34,000**	10.6	<0.30	<0.45*	1.68	8,830	<0.04	352.5	7.85	382	18.8	4.39	<0.30
299-W14-72	23,100	8.9	<0.40	<0.45	<1.40	8,230	<0.04	236.8	7.83	388	18.2	2.62	<0.40
299-W15-11	15,700	1.1	<0.30	<1.00**	<1.60	8,280	<0.04	341.3	7.92	492	19.0	0.99	<0.30
299-W15-152	18,300	0.3	<0.08	<0.09	<0.27	8,936	<0.04	385.3	7.52	513	20.8	0.86	<0.08
299-W15-17	10,335	0.3	<0.30	<1.0*	<1.60	7,355	<0.04	352.7	7.75	357	18.7	2.03	<0.30
299-W15-33	15,900	0.8	<0.08	<0.09	<0.27	8,420	<0.04	247.8	8.07	504	19.0	1.45	<0.08
299-W15-37	13,500	5.3	<0.30	<1.0*	3.10	7,360	<0.04	332.0	8.28	411	22.0	4.78	<0.30
299-W15-42	52,300	3.8	<0.08	<0.09	<0.27	8,520	<0.04	370.1	7.81	658	21.5	0.76	<0.08
299-W15-46	16,200	0.9	<0.08	<0.09	<0.27	8,260	<0.04	381.2	7.91	488	20.1	0.91	<0.08
299-W15-49	17,800	0.9	<0.30	<1.00**	1.78	10,450	<0.04	199.4	7.97	459	19.2	2.18	<0.30
299-W15-50	19,200	2.3	<0.08	<0.09	<0.27	8,370	<0.04	191.0	7.91	520	19.7	0.65	<0.08
299-W15-7	22,300	3.1	<0.30	<1.00**	<1.6	7,980	<0.04	110.4	7.82	548	20.5	12.80	<0.30
299-W15-763	30,833	5.0	<0.20	<0.23	<0.68	10,335	<0.04	186.4	7.73	571	20.9	4.86	<0.20
299-W15-765	17,250	1.9	<0.30	<1.00**	<1.60	8,860	<0.04	215.7	7.78	387	18.2	4.55	<0.30
299-W15-83	15,850	0.4	<0.08	<0.09	<0.27	8,720	<0.04	346.3	7.79	506	19.9	1.42	<0.08
299-W15-94	14,867	0.4	<0.30	<1.0*	3.02	8,924	<0.04	367.1	7.84	519	19.4	1.01	<0.30

Table 3-8. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in Contaminant Monitoring Well Network in 2015

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 (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W18-1	29,300	0.3	<0.08	<0.09	<0.27	8,310	<0.04	338.4	7.74	566	19.2	1.62	<0.08
299-W18-15	11,900	0.9	<0.30	<1.00*	<1.60	5,220	<0.04	337.4	8.47	350	15.7	4.56	<0.30
299-W18-16	19,700	1.9	<0.08	<0.09	<0.27	13,040	<0.04	394.9	7.78	1682	22.6	3.54	<0.08
299-W18-21	40,000	<0.3	<0.30	<1.00*	<1.60	6,910	<0.04	327.8	7.81	581	17.5	4.46	<0.30
299-W18-22	8,100	0.2	<0.08	<0.09	<0.27	7,510	<0.04	169.2	7.71	374	18.3	1.89	<0.08
299-W18-40	11,200	3.7	<0.30	<1.00**	<1.60	13,290	<0.04	219.9	7.65	392	20.4	4.04	<0.30
299-W19-105	3,830	0.7	<0.30	<1.00*	<1.60	8,900	<0.04	335.1	7.81	260	19.5	1.55	<0.30
299-W19-107	13,900	1.9	<0.08	<0.09	<0.27	8,460	<0.04	274.8	7.82	536	19.6	0.58	<0.08
299-W19-18	14,900	<0.1	<0.08	<0.09	<0.27	10,340	<0.04	294.0	9.53	234	16.7	41.70	<0.08
299-W19-34A	20,200	6.1	<0.30	<1.00**	<1.60	10,200	<0.04	238.2	7.96	415	19.2	7.83	<0.30
299-W19-34B	9,040**	9.8	<0.30	<1.00**	<1.60	3,620	<0.04	336.1	7.76	352	19.7	0.85	<0.30
299-W19-36	16,500	2.2	<0.08	<0.09	<0.27	7,270	<0.04	359.0	7.72	1899	21.0	1.74	<0.08
299-W19-4	31,600	1.4	<0.08	<0.09	<0.27	8,260	<0.04	378.0	7.88	656	22.1	18.5	<0.08
299-W19-41	9,300	4.4	<0.30	<1.00**	2.52	7,970	<0.04	153.4	8.52	313	18.6	4.46	<0.30
299-W19-47	12,100	5.8	<0.30	<1.00*	<1.60	8,560	<0.04	249.1	7.85	377	18.9	3.34	<0.30
299-W19-48	7,660	1.3	<0.08	<0.09	<0.27	8,850	<0.04	422.2	7.83	402	20.5	2.00	<0.08
299-W19-49	10,867	3.2	<0.30	<1.00*	<1.60	8,750	<0.04	331.4	7.76	429	19.6	3.18	<0.30
299-W19-6	5,720*	3.6	<0.30	<1.00*	1.92	6,280	<0.04	242.1	7.93	289	18.8	4.58	<0.30

Table 3-8. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in Contaminant Monitoring Well Network in 2015

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 (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
299-W21-2	11,100	1.6	<0.30	<0.09*	<1.60	7,550	<0.04	136.9	7.87	411	22.2	6.74	<0.30
299-W22-47	5,785	3.1	<0.30	<0.30**	<1.60	7,990	<0.04	223.4	7.85	259	17.7	1.40	<0.30
299-W22-72	7,960	3.1	<0.30	<1.00**	<1.60	7,300	<0.04	381.0	7.78	305	21.2	4.12	<0.30
299-W22-86	7,235	1.4	<0.30	<0.09*	<1.60	7,510	<0.04	414.0	7.69	310	21.0	1.66	<0.30
299-W22-87	3,880	0.6	<0.08	<0.09	<0.27	8,830	<0.04	125.2	7.97	242	19.8	1.83	<0.08
299-W22-88	16,300	1.7	<0.30	<1.00**	<1.60	8,730	<0.04	132.7	7.87	358	21.2	4.69	<0.30
299-W23-19	11,867	2.2	<0.30	<1.00**	<1.60	7,950	<0.04	31.8	7.73	507	18.9	3.62	<0.30
299-W23-4	8,010	1.7	<0.08	<0.09	<0.27	8,760	<0.04	321.9	7.98	304	16.3	8.74	<0.08
299-W26-13	6,377	0.4	<0.30	<0.09*	<1.60	8,608	<0.04	186.6	7.91	302	18.4	3.24	<0.30
299-W27-2	17,900	0.7	<0.30	<0.09*	<1.60	6,690	<0.04	154.5	7.73	351	17.5	7.25*	<0.30
299-W5-2	***	3.6	<0.08	***	<0.27	8,917	***	82.3	7.61	433	20.7	143.9	<0.08
299-W6-3	7,600	0.8	<0.08	<0.09	<0.27	4,410	<0.04	157.9	7.99	716	17.1	3.03	<0.08
299-W6-6	41,300	<0.3	<0.30	<1.00*	<1.60	13,330*	<0.04	208.3	7.56	606	15.5	4.58	<0.30
299-W7-3	5,240	0.8	<0.08	<0.09	<0.94	6,903	<0.04	285.5	8.09	293	17.2	2.04	<0.19
699-30-66	9,690	0.9	<0.08	<0.09	<0.27	7,380	<0.04	353.4	7.71	392	20.8	0.78	<0.08
699-32-62	8,560	0.6	<0.08	<0.09	<0.27	7,860	<0.04	309.5	8.05	347	18.9	4.13	<0.08
699-32-72A	13,200	0.7	<0.30	<1.00*	<1.60	4,190	<0.04	108.8	7.89	333	21.8	6.00	<0.30
699-33-75	9,830	0.4	<0.30	<1.00**	<1.60	7,635	<0.04	268.3	7.78	304	19.9	1.99	<0.30

Table 3-8. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in Contaminant Monitoring Well Network in 2015

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 (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
699-34-61	9,330	0.9	<0.30	<1.00*	<1.60	8,570	<0.04	292.5	7.91	360	16.8	38.70	<0.30
699-35-66A	12,150	1.1	<0.30	<1.00*	<1.30	6,410	<0.04	196.9	7.99	385	21.1	144.61	<0.30
699-35-78A	12,300	0.6	<0.30	<1.00*	<1.60	6,570	<0.04	233.9	7.92	296	16.2	4.38	<0.30
699-36-61A	10,100*	0.4	<0.08	<0.09	<0.27	6,680	<0.04	216.3	7.85	384	21.9	2.72	0.08
699-36-66B	20,567	0.7	<0.30	<1.00*	<1.28	7,810	<0.04	364.7	7.91	481	21.6	1.03	<0.30
699-36-70A	12,500	0.7	<0.30	<0.09*	<1.00	9,320	<0.04	189.8	7.87	375	18.1	18.45	<0.30
699-36-70B	18,300	2.8	<0.30	<1.00*	<1.60	7,840	0.06	352.0	7.81	523	23.7	5.92	<0.30
699-37-66	16,850	0.7	<0.30	<1.00*	<1.24	9,250	<0.04	385.2	7.78	621	21.6	3.37	<0.30
699-38-61	12,500	0.3	<0.08	<0.09	<0.27	8,630	<0.04	173.2	7.84	400	19.8	2.17	<0.08
699-38-65	18,000	0.5	<0.30	<0.09*	<1.60	3,230	<0.04	77.4	8.00	648	22.5	5.47	<0.30
699-38-68A	30,900	1.2	<0.08	<0.09	<0.27	10,520	<0.04	410.7	7.16	873	18.5	139.00	<0.08
699-38-70B	24,300	8.3	<0.30	<0.23*	<1.60	9,950	<0.04	302.0	7.78	424	20.4	4.69	<0.30
699-38-70C	26,100	2.7	<0.08	<0.09	<0.27	9,290	<0.04	313.0	7.67	714	21.4	0.28	<0.08
699-40-62	14,000	0.2	<0.08	<0.09	<0.27	8,280	<0.04	191.4	8.01	557	20.5	2.17	<0.08
699-40-65	24,400	1.3	<0.30	<1.00**	<1.60	8,710	<0.04	57.6	7.94	762	21.1	1.29	<0.30
699-43-69	27,600	5.4	<0.08	<0.09	<0.27	10,870	<0.04	391.3	7.88	487	20.7	5.64	<0.08
699-44-64	24,000	1.1	<0.08	<0.09	<0.27	7,180	<0.04	348.9	7.99	492	21.2	4.83	<0.08
699-45-69A	17,800	2.6	<0.08	<0.09	<0.27	16,370	<0.04	179.3	8.05	454	19.5	2.84	<0.08

Table 3-8. Average Concentrations of Natural Attenuation Daughter Products and Field Parameters in Contaminant Monitoring Well Network in 2015

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 (Nephelometric Turbidity Unit)	Vinyl Chloride (µg/L)
699-45-69C	22,900	1.3	<0.08	<0.09	<0.27	10,040	<0.04	405.4	7.79	714	20.7	2.27	<0.08
699-47-60	10,400	<0.3	<0.30	<1.00*	<1.60	7,340	<0.04	17.6	8.27	378	17.8	5.60	<0.30
699-48-71	8,800	3.1	<0.30	<1.00**	<1.60	8,990	<0.04	301.6	7.96	905	18.2	9.99	<0.30
699-50-74	2,060	0.7	<0.08	<0.09	<0.27	10,900	<0.04	287.0	8.08	280	19.4	0.56	<0.08
699-51-63	14,100	<0.3	<0.30	<1.00*	<1.60	7,830	<0.04	253.0	8.10	369	20.3	0.50	<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 2014 data; no data available for 2015

** = calendar year 2013 results; no data available for 2014 or 2015

*** = calendar year 2015, no data results for constituent

In 2015, TCE concentrations in 200-ZP-1 wells declined an average of 30 percent 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 13,500 pCi/L in 2015, which is a 99 percent 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.

3.3.3.1 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 did not exceed 2,000 µg/L in 2015. 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 3-20 shows the approximate carbon tetrachloride footprint (inset a) above the Ringold Lower Mud and (inset b) below the Ringold Lower Mud, as derived from the three-dimensional distribution that was prepared for use as initial conditions in the groundwater contaminant fate and transport modeling (see Section 3.3.4 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.

3.3.3.2 Contaminant Plume Cross Section

Figure 3-37 provides a visual slice through a three-dimensional 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 3-37 shows the carbon tetrachloride plume extending to the east and vertically, downward from the source areas.

3.3.3.3 New Releases of Contaminants of Concern

There were no identified releases of new COCs during 2015.

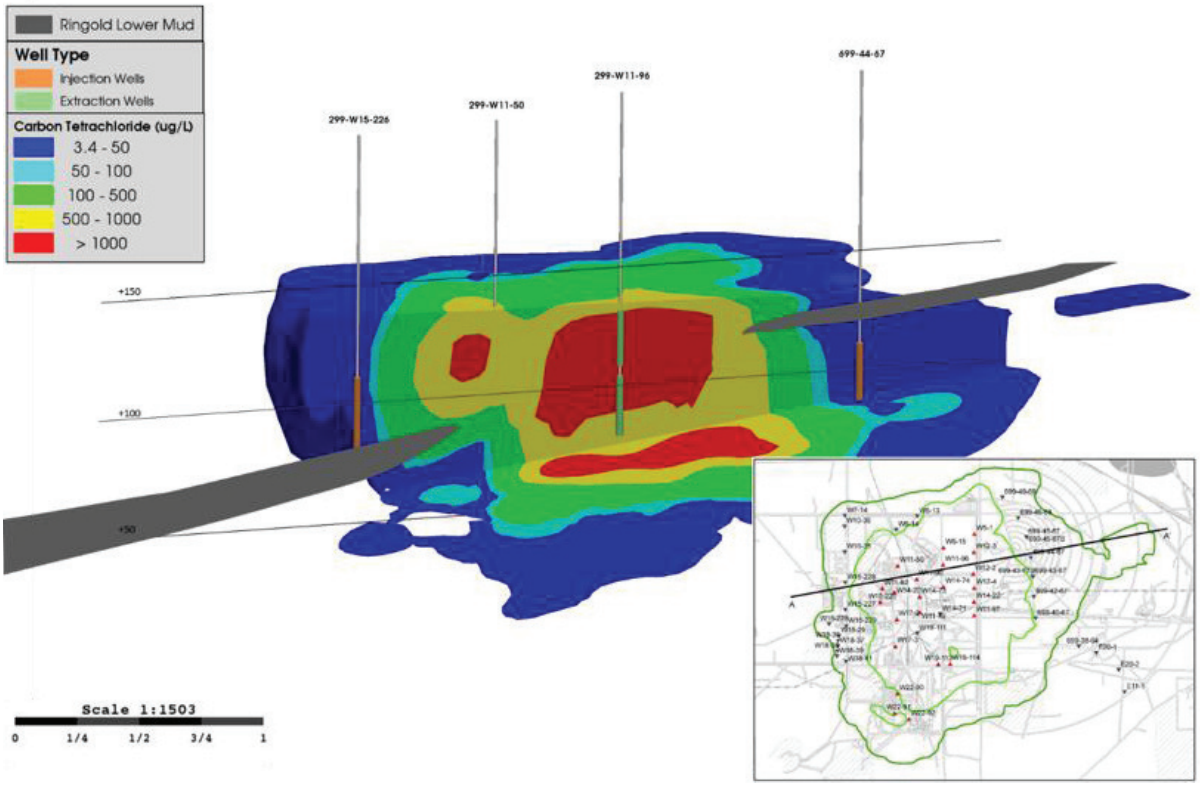


Figure 3-37. 200-ZP-1 OU Carbon Tetrachloride Plume Cross Section A to A'

3.3.3.4 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 3-37). 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.

3.3.3.5 Natural Attenuation Rates and Transformation Products

Sampling to provide data to track natural attenuation and transformation products continued in 2015. 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.

3.3.4 Three-Dimensional Contaminant Plumes

Many of the calculations performed to design the 200 West P&T remedy and to evaluate and optimize remedy performance rely upon three-dimensional depictions of the extent of groundwater contaminated above the cleanup levels established in the 200-ZP-1 ROD (EPA et al., 2008). In particular, sample data are used to construct three-dimensional plume shells as initial conditions for contaminant fate and transport calculations conducted with the Central Plateau Groundwater Model (CPGWM) (CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 6.3.3*). 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.

During CY 2012, the approximate extent of carbon tetrachloride and other COCs in groundwater within the 200 West Area was mapped in three dimensions using ordinary kriging as detailed in ECF-200ZP1-13-0006. At that time, 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. The combination of recent information on carbon tetrachloride concentrations (recent well samples) with less current information was highly informative regarding the vertical distribution of carbon tetrachloride at the time of drilling (characterization data).

The three-dimensional extents of contamination calculated on that occasion have served as the baseline for performance evaluation since that time. Since the data used to prepare those three-dimensional extents are now several years old, it was determined that the three-dimensional depictions would be updated for purposes of this report using data obtained through CY 2015, to update the approximate extent of the COCs in groundwater and provide more current initial condition for modeling purposes. This process is described in this subsection and detailed in ECF-200ZP1-16-0076, *Description of Groundwater Calculations and Assessments for the Calendar Year 2015 (CY2015) 200 Areas Pump-and-Treat Report*.

The approximate current extent of each COC in groundwater was mapped in three dimensions using a combination of kriging and groundwater modeling. The following general steps describe the mapping process (full details of this process are provided in ECF-200ZP1-16-0076):

1. The migration of each three-dimensional COC plume mapped in CY 2012 (ECF-200ZP1-13-0006), and previously used as an initial condition for modeling, was simulated using the CPGWM. The purpose of this step was to migrate the depiction of each COC that was prepared in CY 2012 for 3 years (representing 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 calculated in Step 2 and the corresponding simulated value obtained in Step 1 was calculated. This residual was then handled differently for monitoring wells 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 area of the aquifer, 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 carbon tetrachloride concentration) and the simulated mass recovery obtained under Step 1.

4. The differences calculated in Step 3 represent a three-dimensional 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 three-dimensional scatter of difference ratios was interpolated using ordinary kriging to provide a three-dimensional depiction of the relative difference between the expected (simulated) and measured (sampled) values for each COC throughout 200 West P&T.

5. The three-dimensional relative difference depiction was then multiplied by the simulated carbon tetrachloride depiction for December 2014, providing a three-dimensional depiction of the extent of carbon tetrachloride that generally honors the recently sampled carbon tetrachloride values while reflecting patterns in the distribution of carbon tetrachloride that were reflected in the more comprehensive sample data set used to depict carbon tetrachloride in CY 2012.

To corroborate the resulting depictions for each COC, three-dimensional depictions obtained through the outlined steps were used as the initial conditions in the CPGWM for transport simulations commencing at the beginning and continuing through CY 2015. The simulated mass recovery of each COC was then compared with the measured mass recovery over the same period. Therefore, as documented in ECF-200ZP1-16-0076, improved correspondence was seen between simulated and measured mass recovery using the newly constructed (CY 2015) initial condition, versus the previous CY 2012 initial condition, providing confidence in the newly constructed initial conditions. Sample data used to develop the updated COC depictions are detailed in ECF-200ZP1-16-0076, and both the 200-ZP-1 and 200-UP-1 OU data and the surrounding area data are incorporated. Full details of the three-dimensional interpolation are provided in ECF-200ZP1-16-0076.

3.4 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 to be used to evaluate hydraulic containment and mass recovery. Application of the CPGWM during CY 2015 for remedy simulation purposes is described in ECF-200ZP1-16-0076. As of 2015, the 200 West P&T operated for 3.3 years. The system has not yet operated for a sufficient amount of time to provide a reliable quantitative projection of the likely mass recovery through 2037, although ECF-200ZP1-13-0006 demonstrates the 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 2015. The rates simulated for each 200-ZP-1 extraction and injection well are specified in the model simulations based on rates observed in 2015, as depicted in Figures 3-4 through 3-7. These rates are also depicted in Figure 3-12. Details of the analyses are included as part of the overall calculation results provided in ECF-200ZP1-16-0076. Simulated mass recovery projections presented therein are based upon assumed operating rates that have not recently been subjected to optimization to maximize mass recovery.

Figure 3-38 depicts groundwater elevation contours computed using the CPGWM for the following aquifer intervals and periods:

- Figure 3-38 (inset a): above RLM at the end of 2015
- Figure 3-38 (inset b): below RLM at the end of 2015

The simulated water table elevations and spacing of contours (equipotentials) compare favorably with the depictions computed using water level mapping (Figure 3-17), 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 and there is less monitoring density, the mapped and modeled water levels show more notable differences.

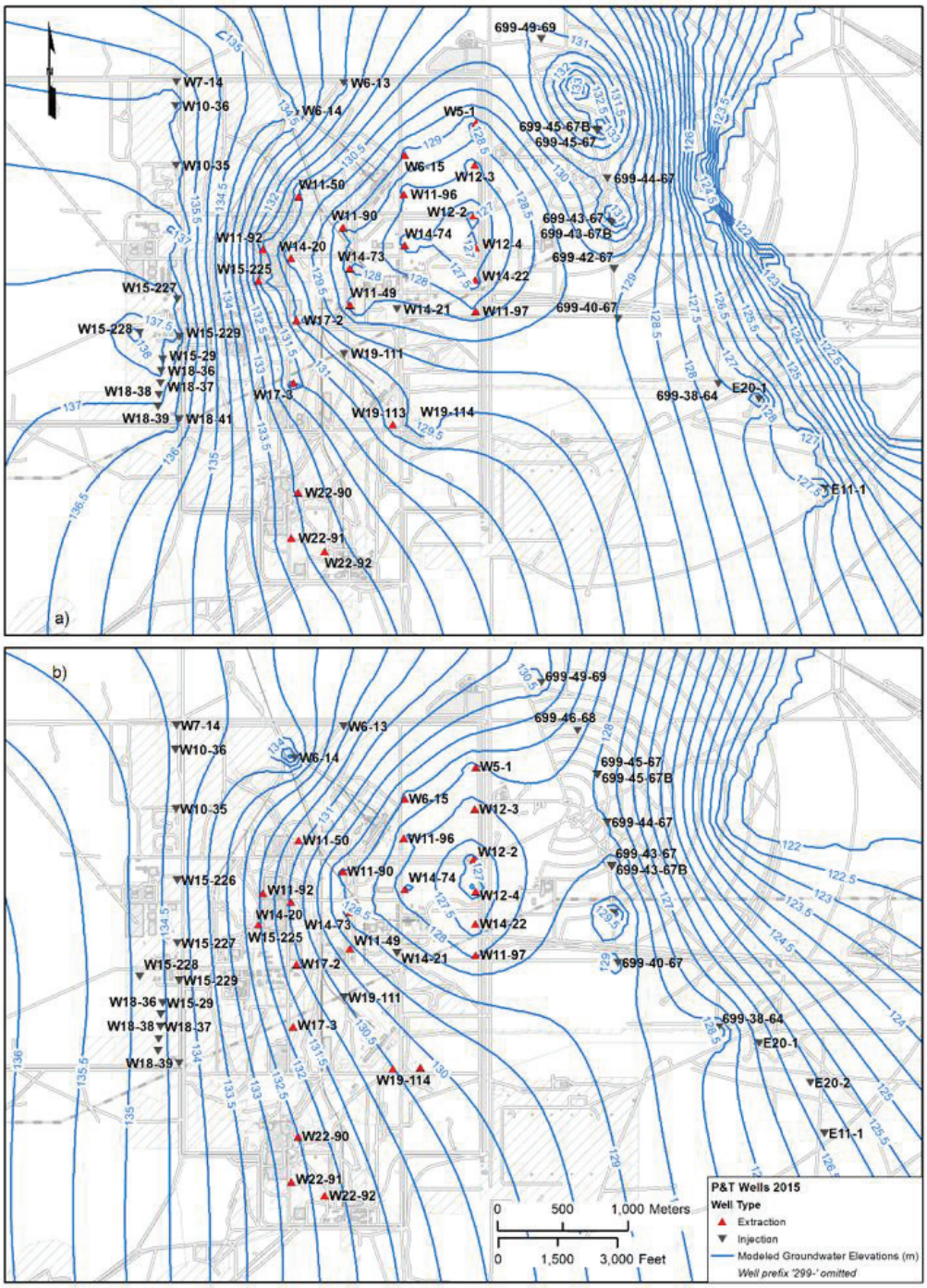


Figure 3-38. Groundwater Elevation Contours Computed Using the CP Model: (a) above the RLM at the End of 2015; (b) below the RLM at the End of 2015

Figures 3-39 and 3-40 depict unadjusted and adjusted drawdown and mounding estimated using the CPGWM for the following aquifer intervals and periods (the adjustment that is applied is described in Section 3.2.2.1):

- Figure 3-39 (inset a): above RLM at the end of 2015 (not adjusted for regional water level declines)
- Figure 3-39 (inset b): below RLM at the end of 2015 (not adjusted for regional water level declines)
- Figure 3-40 (inset a): above RLM at the end of 2015 (adjusted for regional water level declines)
- Figure 3-40 (inset b): below RLM at the end of 2015 (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 3-18). 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 3-41 depicts the simulated extent of hydraulic containment for December 2015 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 3-41 is approaching the size that which be developed by the remedy when it is operating at 7,571 L/min (2,000 gpm).

3.5 Contaminant Transport Modeling

This report describes contaminant transport analyses for conditions since the inception of the 200-ZP-1 P&T remedy through CY 2015 by the 200 West P&T; full details of the calculations are presented in ECF-200ZP1-16-0076. 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 RAO outlined in the 200-ZP-1 ROD (EPA et al., 2008), which is discussed in Section 3.6

Figures 3-42 and 3-43 present comparisons of the simulated and measured carbon tetrachloride influent concentrations for the 200 West Area extraction wells since startup of the system in the summer of 2012. Simulated influent concentrations shown in Figure 3-42 assume a 100-year half-life for the degradation of carbon tetrachloride, whereas those in Figure 3-43 assume a 41-year half-life. Similar figures are presented in ECF-200ZP1-16-0076 for the other 200-ZP-1 OU COCs. 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.

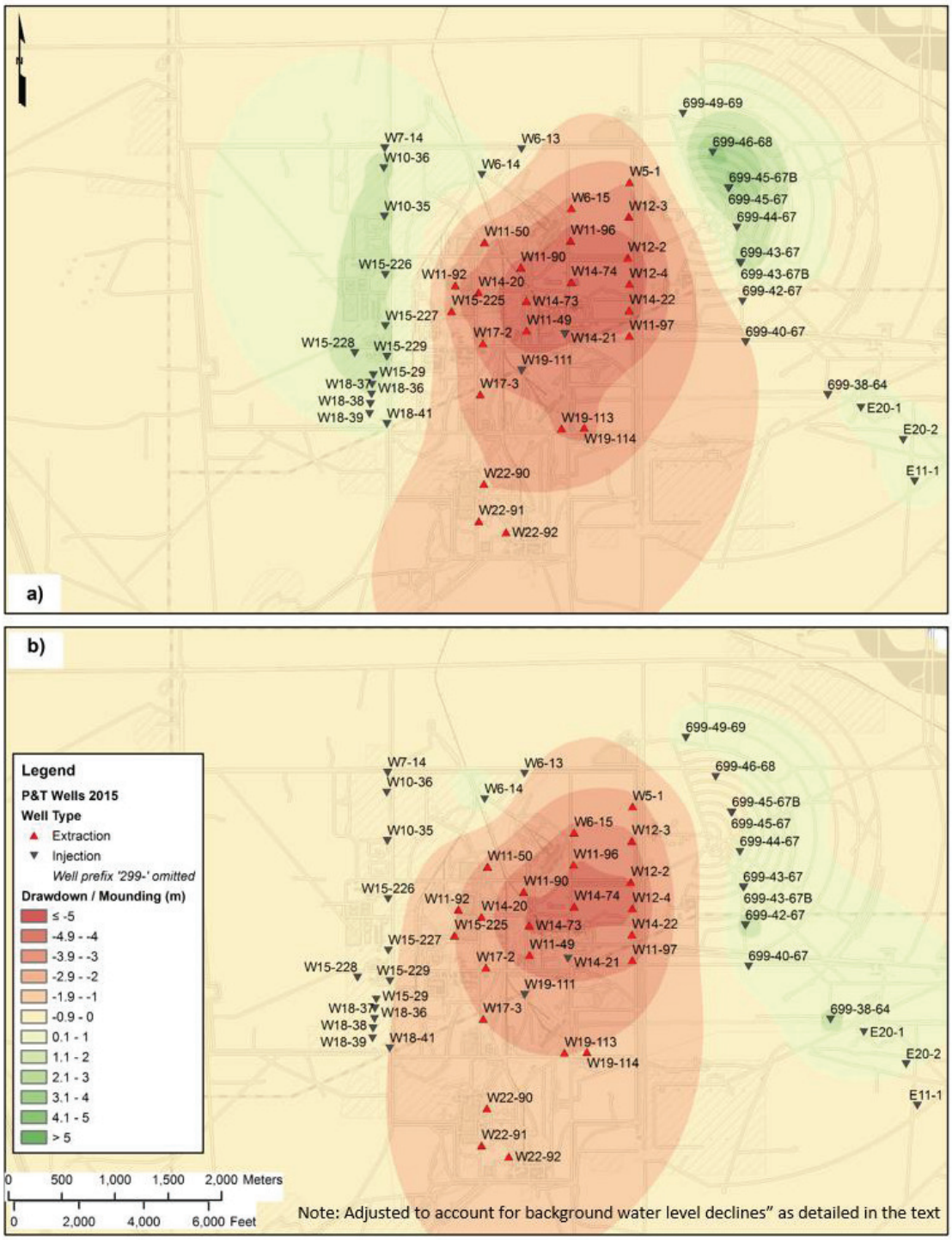


Figure 3-39. Unadjusted Drawdown and Mounding Estimated Using the CP Model: (a) Unadjusted Drawdown above the RLM at the End of 2015; (b) Unadjusted Drawdown below the RLM at the End of 2015

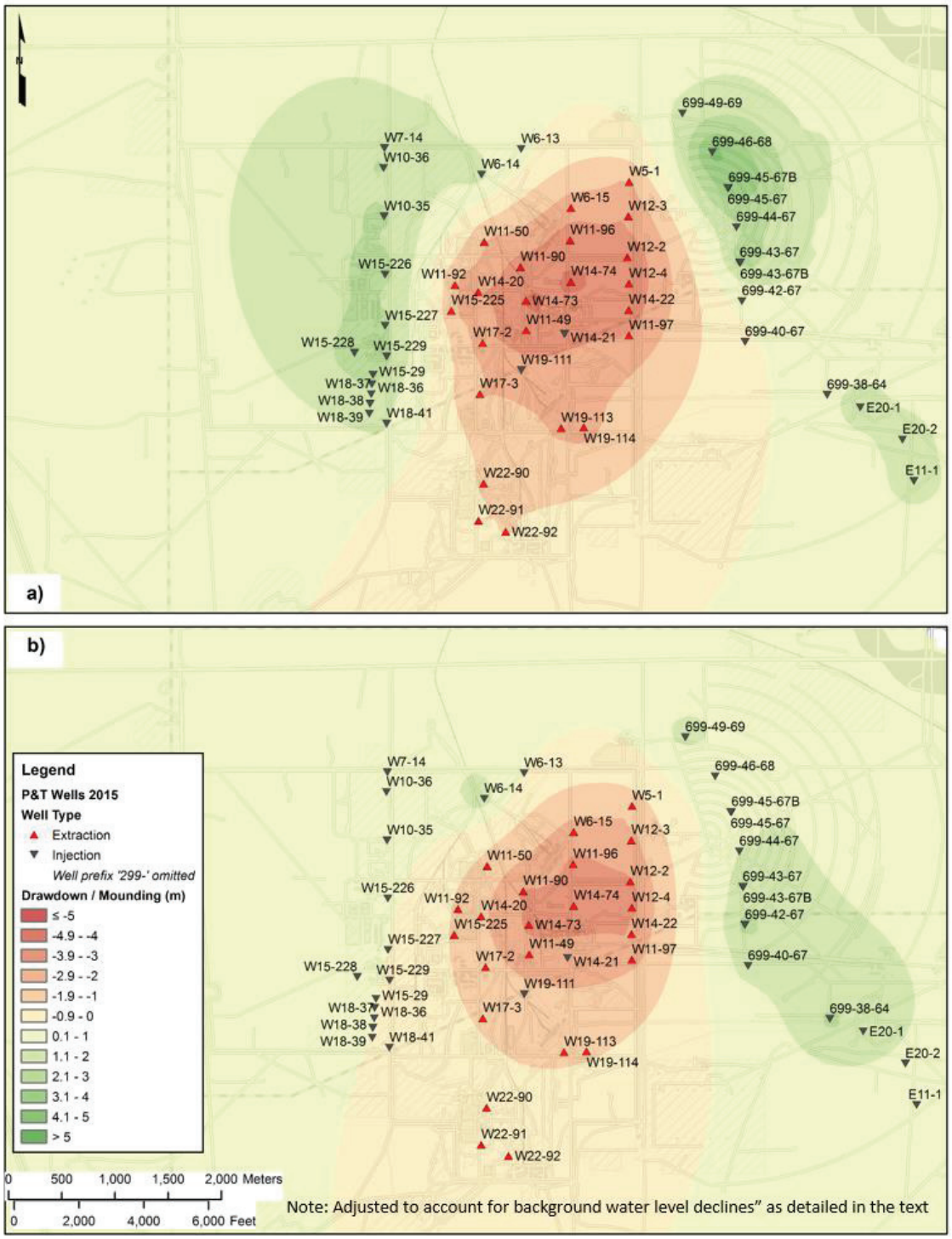


Figure 3-40. Adjusted Drawdown and Mounding Estimated Using the CP Model: (a) Adjusted Drawdown above the RLM at the End of 2015; (b) Adjusted Drawdown below the RLM at the End of 2015

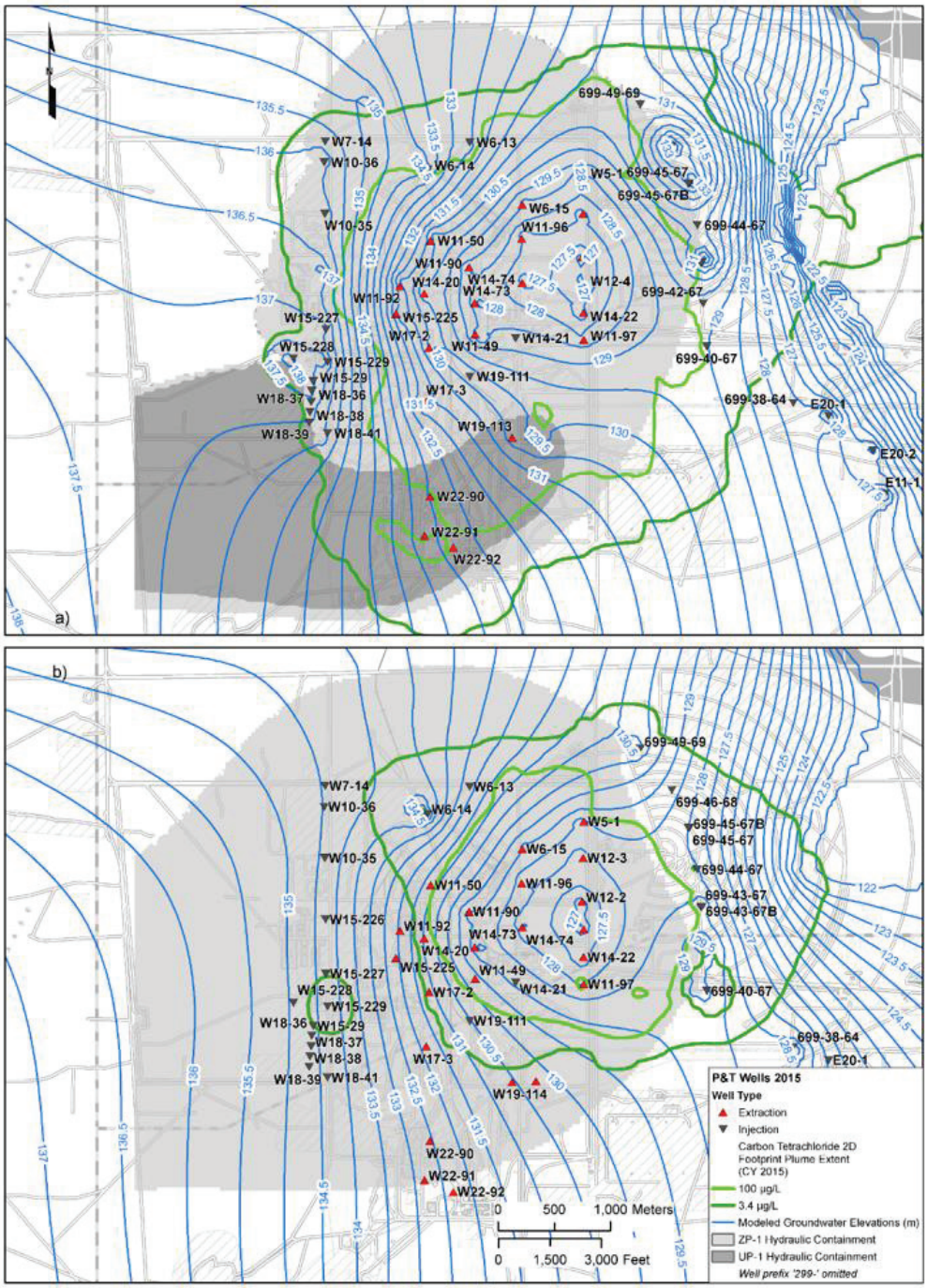


Figure 3-41. Extent of Hydraulic Containment Computed for December 2015 Using the CP Model: (a) above the RLM; (b) below the RLM

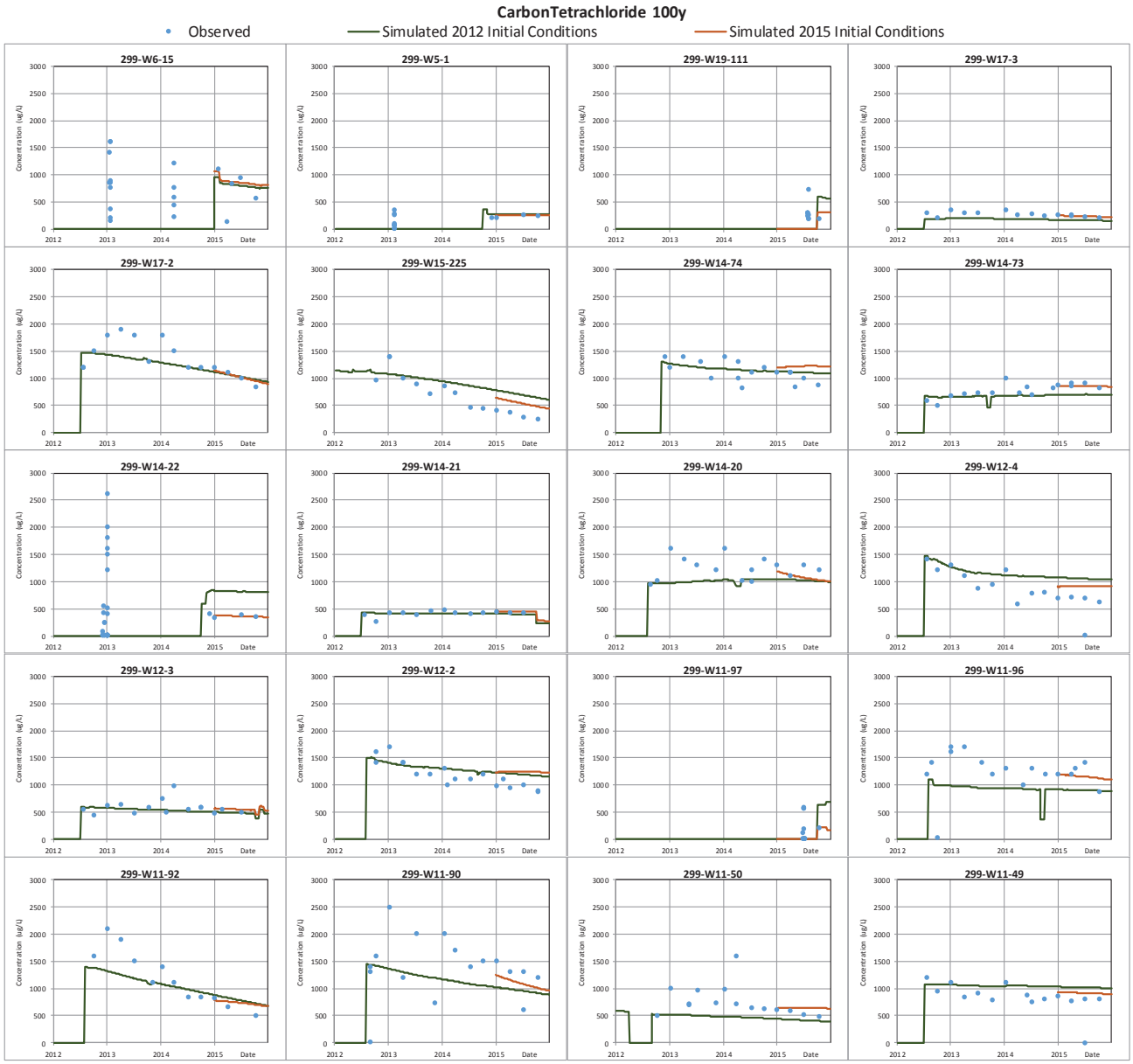


Figure 3-42. Simulated and Measured Carbon Tetrachloride Concentrations at Extraction Wells Assuming 100-Year Half-Life

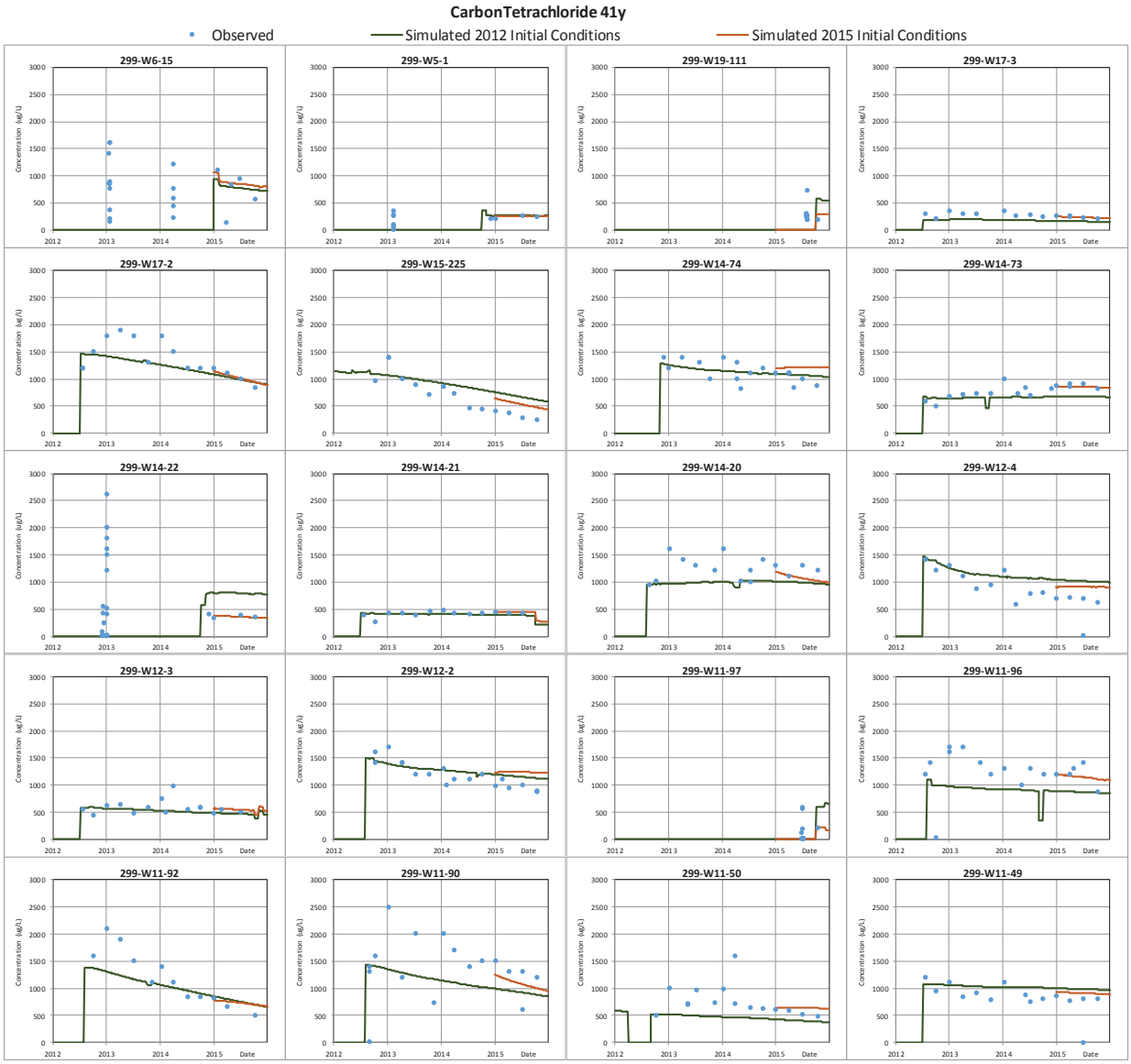


Figure 3-43. Simulated and Measured Carbon Tetrachloride Concentrations at Extraction Wells Assuming 41-Year Half-Life

Figure 3-44 presents comparisons of the simulated and measured carbon tetrachloride mass recovery for the 200 West P&T since startup of the system in the summer of 2012. Simulated mass recovery in Figure 3-44 (inset a) assumes a 100-year half-life for the degradation of carbon tetrachloride, whereas those in Figure 3-44 (inset b) assume a 41-year half-life. The figures also show the projected mass recovery for the planned operational life of the P&T remedy (i.e., through 2037). Similar figures are presented in ECF-200ZP1-16-0076 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 exceeded the simulated recovery.

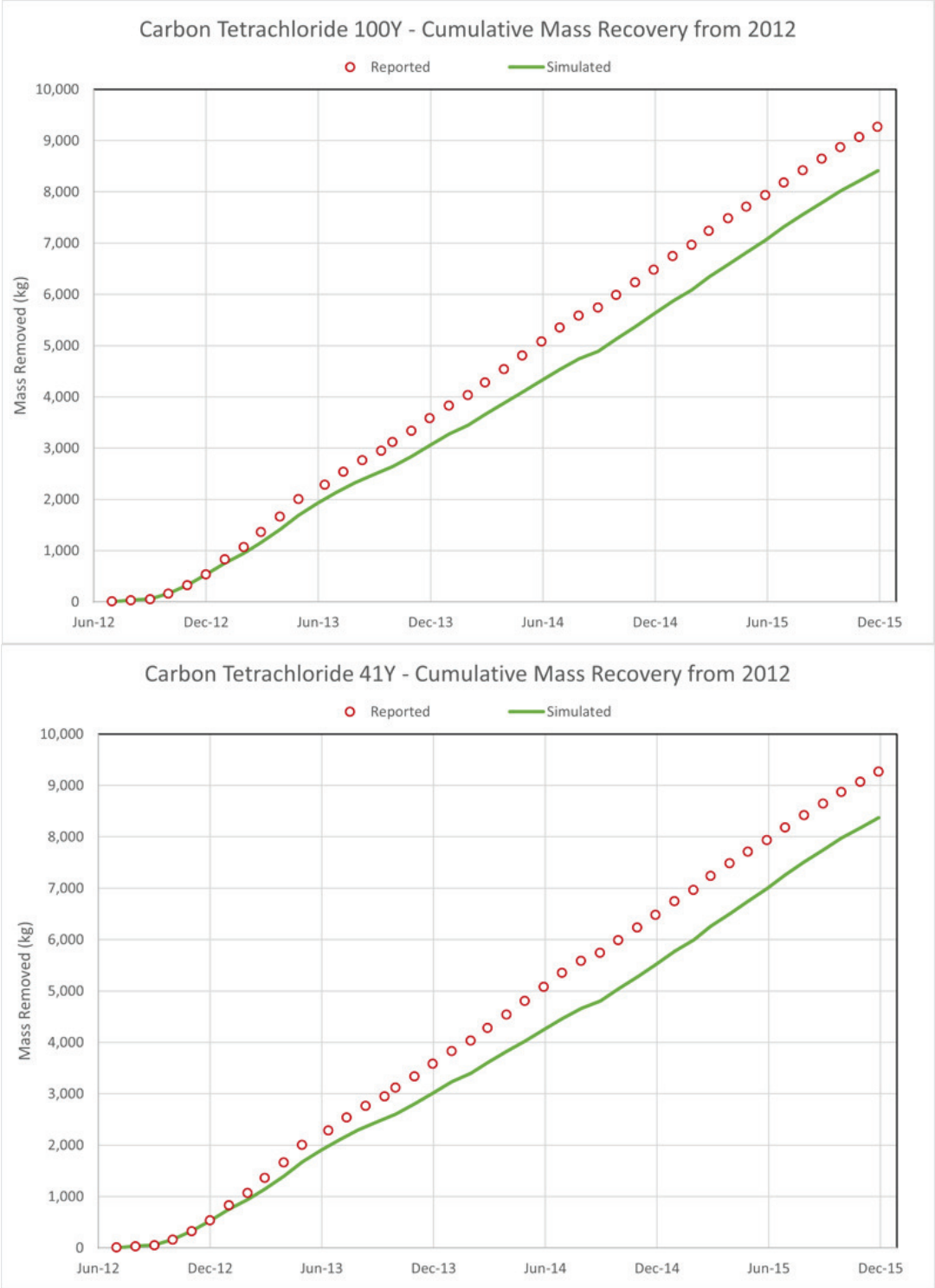


Figure 3-44. Simulated and Measured Carbon Tetrachloride Mass Recovery Assuming (a) 100-Year Half-Life and (b) 41-Year Half-Life

The CPGWM is updated each CY to incorporate actual (monthly averaged) extraction and injection rates in order to minimize differences between actual and simulated flows. As a result, the higher measured mass recovery depicted in Figure 3-44 may indicate that more mass was present in the subsurface than represented in the initial plume shell, or some transport simulation parameters may 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, thus improving the reliability of longer term mass recovery projections.

3.6 Progress Toward Meeting Remedial Action Objectives

This section evaluates progress toward attaining the RAOs outlined in the ROD (EPA et al., 2008). Until sustained flow rates reach design rate, this evaluation should be interpreted as preliminary, with the expectation that the evaluation and projections will be refined in future annual reports as additional performance monitoring data are acquired. Over time, the findings of these collective assessments will be used along with additional data and analyses to guide the optimization of the remedy to achieve the RAOs set forth in the 200-ZP-1 ROD (EPA et al., 2008).

The following progress for the 200 West P&T is evaluated in this section:

- 2012 through 2015 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 2015 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
- Likely future performance of the 200 West P&T component of the remedy in terms of recovering contaminant mass that is projected using the CPGWM, which is not presented in this report at this time because the remedy is not yet operating at full design rates

3.6.1 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. Since the majority of contaminant mass lies within this iso-concentration line, focusing hydraulic containment on this area will maximize the efficiency of mass recovery.

Figure 3-41 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 mass recovery). Figure 3-19 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 6,000 L/min (1,600 gpm) for the 200-ZP-1 extraction wells, with additional groundwater recovery by the 200-UP-1 extraction wells also contributing 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 was almost entirely contained by pumping in the 200 West Area as

of 2015. Importantly, the area that is depicted as being hydraulically contained is shown to be larger than the area estimated to be contaminated at concentrations above 100 µg/L, which suggests that as currently operating, the P&T system can produce a region of hydraulic containment that is larger than the area targeted for containment; thus, remedial optimization should be successful in achieving hydraulic containment of the entire region at concentrations above 100 µg/L. It is also noted that the extent of hydraulic containment depicted in these figures is smaller than that which will be developed when the final 200-ZP-1 remedy is operating at the design rate of 7,600 L/min (2,000 gpm). Planned rate increases and rebalancing of groundwater extraction and reinjection are, therefore, anticipated to improve hydraulic containment in this area.

3.6.2 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 not only the extent of hydraulic containment but also the presence of reduced hydraulic gradients to the northeast and southeast of the 200-ZP-1 OU. Evaluations for the development of flow-path control rely on the integrated 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. The methodology used to evaluate flow-path control is provided in 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*.

Figures 3-45 and 3-46 depict estimated reductions in hydraulic gradients above and below the RLM, respectively. Since natural gradients in this area would be to the east, reduction in the hydraulic gradient is indicated by arrows pointing toward the west, and the magnitude of reduction is indicated by length of the arrows. Greater hydraulic gradient reduction and flow-path control are observed between the extraction and injection wells, and less gradient reduction is observed further away from the extraction and injection wells. In particular, gradient reduction is less evident moving further 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 more detail after the 200 West P&T has been running at full capacity for a sufficient time to stabilize hydraulic gradients. As of 2015, the 200 West P&T has operated for about 3.3 years, and extraction and injection wells are still being added to bring the system to full capacity; therefore, the full extent of flow-path control is still being established.

3.6.3 Evaluation of Contaminant of Concern Mass Removal Goal

Progress toward achieving the RAOs will be evaluated after the 200 West P&T has been running at full capacity for a long enough period for the hydraulic gradients to stabilize. As of 2015, the 200 West P&T had operated for about 3.3 years, and extraction and injection wells are still being added to bring the system to full capacity; therefore, the rates of mass recovery are still being established.

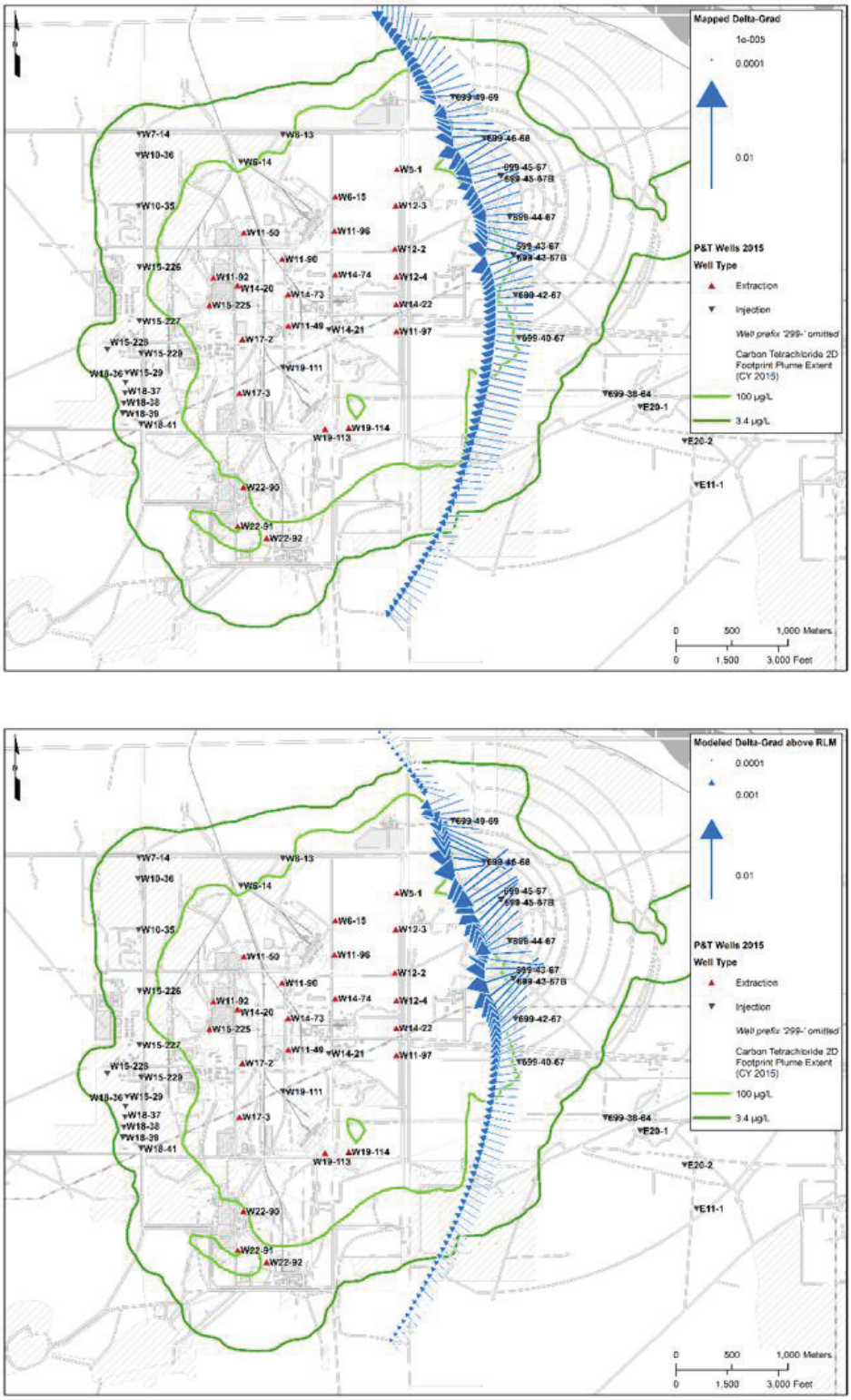


Figure 3-45. Gradient Changes along Line of Control above the RLM: (a) Mapped and (b) Modeled

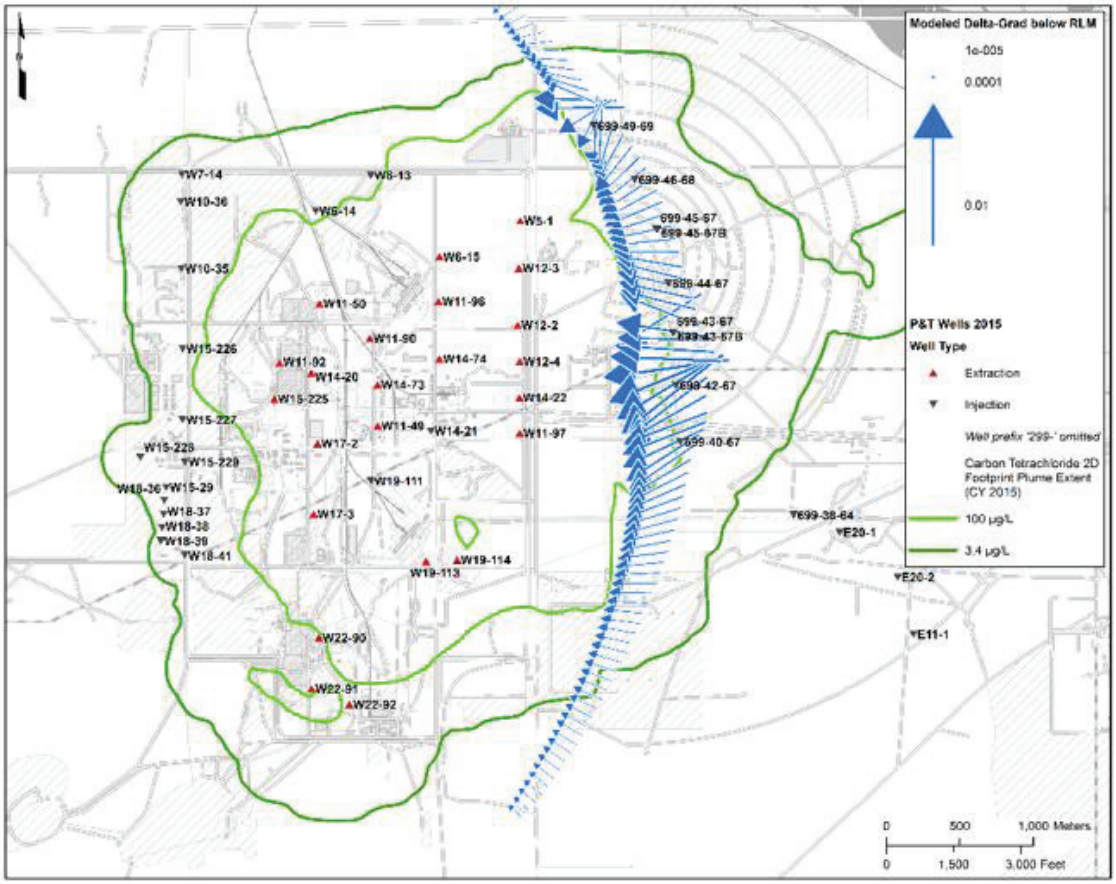


Figure 3-46. Gradient Changes along Line of Control below the RLM (Modeled)

As discussed previously, ECF-200ZP1-15-0002 introduced calculation methods based upon the results of groundwater flow modeling and contaminant transport modeling to compare observed and predictive containment and mass removal towards achieving the RAOs. These calculation methods will be applied in future annual reports after the 200 West P&T has been running at full capacity during a long enough period for the hydraulic gradients to stabilize. An application of these transport calculation methods for predictive contaminant transport simulations and comparison of observed to simulated extraction well concentrations and mass removal, as updated through CY 2015, are provided in ECF-200ZP1-16-0076.

3.7 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 3-1). 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 0.0 km^2 (0.2 to 0.0 mi^2). From 1996 to May 2012, the interim system removed 13,718 kg of carbon tetrachloride from groundwater. In 3.3 years of operation since July 2012, the 200 West P&T successfully treated groundwater to cleanup levels for all COCs, removing 9,264 kg of carbon tetrachloride; 844,113 kg of nitrate as nitrate (190,601 kg of nitrate as nitrogen); 250 kg of chromium; 37 kg of TCE; and 284 g of technetium-99.

- **RAO #2:** Apply ICs to prevent the use of groundwater until the cleanup levels (Table 3-1) 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.

3.8 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-2016-09. 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.

3.9 200 West P&T Facility System Costs

This section presents the actual cost breakdown for 200 West P&T operations for 2015, and the cost per unit mass is calculated for specific COCs. 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.
- **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 RD/RAWP (DOE/RL-2008-78), 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 granular activated carbon, 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 CERCLA monitoring, extraction, and injection wells within the 200-ZP-1 OU.

Table 3-9 provides costs for the 200 West P&T. Most of the costs from 2009 through 2012 (89.4 percent) 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 3-9 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.

Total cost for the 200 West P&T during 2015 was $25.6 million (sum of the categories shown in Table 3-9), which is an 8.6 percent reduction from the total cost in 2014 of $28.0 million. The higher 2014 costs were primarily associated with additional well construction and connection to the 200 West P&T during that year. The percentage of 2015 costs, in decreasing order, includes O&M (73.6 percent), well installation (12.9 percent), treatment system capital (9.8 percent), performance monitoring (1.3 percent), waste management (1.0 percent), regeneration (0.6 percent), project support (0.5 percent), and design (0.3 percent).

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 2015 O&M cost was $18.8 million. In 2015, the 200 West P&T treated 3,831.5 million L (1,012.2 million gal), removing a combined total of 351,320 kg of contaminants (primarily carbon tetrachloride [2,786 kg], nitrate as NO_3 [348,431 kg], chromium [83.5 kg], and TCE [11.0 kg]). The cost for groundwater treatment in 2015 was $0.01/L, and the cost for contaminant mass removal in 2015 was $84.6/kg.

Table 3-9. Cost Breakdown for the 200 West P&T

Description	Actual Costs (in Thousands of Dollars)						
	2009	2010	2011	2012	2013	2014	2015
Design	7,981.7	4,563.6	—	—	—	—	70.1
Treatment System Capital	4,631.5	55,476	141,525.1	27,725	—	—	2,514.5
Project Support	9.5	113.6	48.4	310.3	451.7	$354	136.4
Operations and Maintenance	5.7	2,303.2	289.1	12,693	18,460.9	19,046.4	18,833.5
Performance Monitoring	—	96.5	54.6	349	$531.9	243.5	331.4
Waste Management	—	—	—	40.5	$485.5	226.7	260.6
Regeneration Subcontract	—	—	—	—	$22.4	204.5	145.2
Well Installation	4,240	4,959	3,136.2	1,394.3	1,687.6	7,924.6	3,302.8
Totals	**16,868.4**	**67,511.9**	**145,053.4**	**42,512.1**	**21,640**	**27,999.8**	**25,594.5**

— = not applicable

3.10 Conclusions

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

- During 2015, data obtained from the 200 West P&T demonstrated that it is capable of operating at its nominal design capacity of 9,092 L/min (2,000 gpm). The average facility throughput in 2015 from the 26 extraction wells pumping to the 200 West P&T is 7,447 L/min (1,966 gpm) with a maximum combined pumping rate of 8,311 L/min (2,194 gpm). This is a 26 percent increase over the 2014 throughput of 5,920 L/min (1, 564 gpm). The increase is mainly attributed to flows from 200-UP-1 and 200-BP-5 OU feed streams. The average 200-ZP-1 pumping rate was 363 L/min (95.7 gpm) per extraction well in 2015, which is within the range of the design pumping rate of 303 to 492 L/min (80 to 130 gpm). The average pumping rate from the 200-ZP-1 extraction wells increased slightly in 2015 from 329 L/min (86.8 gpm) in 2014.
- During 2015, total water of 3,831.5 million L (1,012.2 million gal) was extracted from the aquifer by the 200-ZP-1 OU, WMA S-SX, 200-UP-1 OU, and 200-BP-5 OU extraction systems, containing an estimated 2,786 kg of carbon tetrachloride; 348,431 kg of nitrate; 84 kg of chromium (total and hexavalent); 11 kg of TCE; and 109 g (1.87 Ci) of technetium-99. The total mass removed since startup was 9,264 kg of carbon tetrachloride; 844,113 kg of nitrate; 250 kg of chromium; 284 g (4.84 Ci) of technetium-99; and 37 kg of TCE.
- During 2015, the 200 West P&T successfully treated influent contaminant concentrations to below cleanup levels for all constituents prior to reinjection into the aquifer.

- Proper balancing of micronutrients in the FBRs restored the health of the microorganisms in 2013. Healthy microorganisms in the FBRs reduced nitrate concentrations in the effluent to below cleanup levels throughout 2015 (Table 3-5).
- Rehabilitation of injection wells to remove metal oxides and biofilms continued in 2015. Injection wells were taken offline and cleaned to remove clogging material and restore injection capacity.
- As a result of treatment at the 200 West P&T, 2,786 kg of carbon tetrachloride were removed in 2015 compared to 2,989 kg of carbon tetrachloride removed in 2014. Carbon tetrachloride concentrations declined (greater than 20 percent decrease in concentration) in 44 of the 97 monitoring wells in 200 West Area; 23 wells had increasing concentrations (greater than 20 percent increase in concentration); and 30 wells had concentrations about the same as observed in 2012. Many of the wells with increasing concentrations are located near extraction wells that are effectively drawing contamination in from surrounding areas, as expected.
- Chromium concentrations exceeded the 48 µg/L cleanup level in 6 of the 50 monitoring wells in the 200-ZP-1 OU (Table 3-6) and declined (greater than 20 percent decrease in concentration) in 9 of the 50 monitoring wells. Concentrations increased in 19 wells, and 22 wells had concentrations about the same as reported in 2012.
- Iodine-129 concentrations exceeded the 1 pCi/L cleanup level in only 1 of 50 monitoring wells in 2015 and declined in 7 of the 50 monitoring wells in the 200-ZP-1 OU (Table 3-6). Concentrations increased in 1 well but remained less than the 1 pCi/L cleanup level. Low concentrations of iodine-129 were removed to less than detection (less than 0.60 pCi/L) in the IX system since startup of the 200 West P&T.
- Nitrate concentrations are above the cleanup level of 45 mg/L beneath much of the 200-ZP-1 OU (Table 3-6). In 2015, nitrate concentrations declined in 13 wells, increased in 10 wells, and were about the same (less than 20 percent difference) in 27 of the 50 monitoring wells.
- Technetium-99 concentrations exceeded the 900 pCi/L cleanup level in 3 of the 50 monitoring wells in the 200-ZP-1 OU (Table 3-6). Concentrations declined (greater than 20 percent decrease in concentration) in 40 percent of the 200-ZP-1 OU monitoring wells in 2015. Technetium-99 concentrations in the 200 West P&T influent steadily declined from 2,210 pCi/L in August 2012 to 1,780 pCi/L in March 2015.
- TCE exceeds the cleanup level of 1 µg/L beneath most of the 200-ZP-1 OU and is collocated with the high-concentration portion of the carbon tetrachloride plume (Table 3-6). The highest TCE concentration was found in an extraction well. The majority of TCE plumes are located within the capture zone of the 200-ZP-1 extraction wells.
- Capture zones from the extraction wells effectively cover most of the carbon tetrachloride plume at concentrations at 2,000 µg/L or less, 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 is being performed to confirm that concentrations in portions of the plumes not being captured will be reduced to below cleanup levels by MNA.

3.11 Recommendations

The following actions are recommended for the 200-ZP-1 OU:

- Conduct evaluation of 200 West P&T performance through numerical modeling to identify adjustments to operating parameters in order to maximize mass recovery for all COCs while meeting the hydraulic containment and flow-path control objectives.
- Expand the capacity of flow through MBRs, which would allow for higher flow through the 200 West P&T during routine maintenance or cleaning. Currently, when an MBR is taken offline for routine maintenance or cleaning, flow through the 200 West P&T is reduced by 2,271 L/min (600 gpm) until the MBR is brought back online.

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